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SHORE EROSION STUDY
TECHNICAL REPORT

APPENDIX 4

SHORELINE EROSION AND BLUFF STABILITY ALONG LAKE MICHIGAN
AND LAKE SUPERIOR SHORELINES OF WISCONSIN

OZAUKEE COUNTY

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FEBRUARY 1977

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appendix 4

WISCONSIN

COASTAL MANAGEMENT

Wisconsin Coastal Zone Management Program

This report has been prepared through the cooperative efforts of the Wisconsin Geological and Natural History Survey, the University of Wisconsin (Madison, Milwaukee, Parkside and Extension), the Wisconsin Department of Natural Resources and the Office of State Planning and Energy. Assistance was further provided by Owen-Ayres and Associates.

This report is being reproduced quickly and in a limited quantity for dissemination to local governments and interested parties. The report will be broadly available when reproduced in the fall of 1977 as an information circular from the Wisconsin Geological and Natural History Survey.

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INTRODUCTION

This Appendix provides detailed information on shoreline conditions within much of the county. The order of materials in the Appendix is from south to north. Parts of the shoreline are broken down by reach (see County Map) and geographic section within each reach. There is a text which describes the characteristics of shoreline conditions at the beginning of each reach section. This is accompanied by a map of the whole reach which shows the sections, public perception of erosion hazards, shore damage in 1952, short- and long-term recession rates, bluff height, shore protection structures, houses per mile, and boat ramps.

Location of geotechnical borings is indicated on the county map at the beginning of the Appendix. Logs for geotechnical holes and detailed location maps are given at the end of all of the maps in the reach containing that geotechnical site. For each geographic section (one mile long) a map showing the location of shore protection structures which are numbered and described in reports on file with the Department of Natural Resources. Also on the map, locations of measured profiles are shown along the shoreline. A running description of bluff characteristics, materials making up the toe of the slope, and beach characteristics is also given. Engineering data such as safety factor, the confidence level on this safety factor, and the distance the slope must retreat to attain a stable slope angle is also given. It should be noted that this distance assumes no wave cutting at the base of the bluff. This distance is referred to in the text as a stable slope distance. Also included with each section is a set of profiles from the water's edge to the bluff top. These profiles show stratigraphy, slope angles, circles of failure, and calculated safety factors along the shoreline. The dis-

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tance to a 5 foot depth of water is also given. The date when the profile was measured is also given. Remember that the bluff profile could have changed since the profiles were measured.

The meaning of abbreviations used in the Appendix is given on this page. For more detailed description of the methods used in compiling the data, regional interpretations, and conclusions about the engineering characteristics and types of slope failure taking place refer to the main report (Shoreline Erosion and Bluff Stability Along Lake Michigan and Lake Superior Shorelines of Wisconsin) available from the State Planning Office and the Wisconsin Geological Natural History Survey.

Symbols Used

(used as nouns and adjectives)

b	boulders
c	clay or clayey
co	coarse
f	fine
g	gravel
m	medium
p	pebbles
s	sand
si	silt
t	till
y	cobbles
t(1A)	till name
SF	Factor of Safety
	A - unsatisfactory (1.00)
	B - questionable (1.00-1.25)
	C - satisfactory (1.25)
CL	Confidence Level
	A - high confidence - at borehole
	B - medium confidence - near borehole, stratigraphy visible
	C - low confidence - away from borehole, stratigraphy questionable
SL	Stability line - the distance slope must retreat to attain a stable slope angle. This assumes no erosion at toe and unchanged conditions of nature of material and water table.

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SCALE MILES

FIELD REPORT - REACH 11

Location

This reach is located in T. 8 and 9 N., R.22E., Milwaukee and Ozaukee Counties. Its length is approximately 3.5 miles, encompassing the northern 1.5 miles of Milwaukee County and the southern 2 miles of Ozaukee County.

Reach 11A

Part A of reach 11 is an area of Nipissing age (605') lake terrace (Alden, 1918), which extends from the groins in Doctors Park (10.7, T.8N.*) north to section 4.8, T.8N., Land use in this part of reach 11 includes Doctors Park, an Audubon Bird Sanctuary and residential areas. The conditions present in the area are as follows.

The beach width throughout the stretch is greater than 25' and the beach texture grades from cobbles at the water's edge to pebbles to medium-grained sand approximately 12' inward. The medium sand continues to the toe of the terrace. The distance to the 5' depth from the water's edge is about 110 feet.

In places, the remnants of a former beach deposit protect the toe of the terrace. Vegetation on the face of the toe is about 80% and is composed primarily of trees and bushes. This vegetative cover has a stabilizing effect on the toe of the terrace.

The terrace width through section 10 is 300 feet. The terrace has a 100% vegetative cover consisting mainly of grass with isolated patches of trees and bushes. Approximately 50 feet from the foot of the bluff is a thick growth of trees (up to 8" in diam.) and bushes which continue to the top of the bluff. This has a great stabilizing effect on the bluff. The bluff slope which can be seen in profile 1 (section 10) is approximately 25° . This seems to be the

* Refers to location on Figure 1. The number following the decimal refers to the tenth mile north of the south section line.

maximum angle of inclination for a well-vegetated slope to maintain stability in this area. This profile, located at 10.9 in section 10, is typical of the entire stretch.

No failures, seeps, or structures are located in this stretch of section 10. Except for the toe of the terrace, no stratigraphy is visible in section 10 due to the thick vegetative cover.

T.8N., Sections 3 and 4

Sections 3 and 4 are discussed together because the shore configuration is such that very little of section 3 is actually in contact with the shoreline.

The beach conditions in sections 3 and 4 are identical to the conditions in section 10, T.8N.

The vegetation on the toe of the terrace is approximately 80%, and consists mainly of trees and bushes. The width of the terrace decreases gradually in the southern part of sections 3 and 4 to less than 20 feet wide at 4.4. The terrace has a 100% vegetative cover to this point, consisting of grass, trees, and bushes.

The bluff in this stretch of sections 3 and 4 has the same characteristics as in section 10, that being a thick growth of trees and bushes which stabilizes the bluff. The bluff has approximately a 25° slope in this area, with no failures or seeps.

At approximately mile 4.3 in this section, the stratigraphy of the terrace becomes visible where the vegetative cover of the toe of the terrace drops to approximately 10%. The stratigraphy consists of 2 feet of a bluish-gray sandy, silty till overlain by 4 feet of brownish-gray clayey till. The top of the gray clayey till is marked by a boulder layer which is covered by 5 feet of medium-grained sand. A minor seep is located at the upper till-sand contact.

North of mile 4.5 the terrace increases in width. From 4.4 north to 4.5 where minimal terrace was found, the bluff seems to be in a fairly stable

condition. The toe of the terrace is being eroded but no failures were noted on the bluff. No seeps were found. The terrace stratigraphy was continuous from 4.3 through this stretch to 4.6 where it becomes concealed by a structure (a stone revetment).

Although the terrace widens, it never attains a width greater than 150' to where it terminates at location 4.9 in this section. North of the structure at 4.6, vegetation, drift wood, and a concrete boat ramp conceal the stratigraphy of the terrace. From the structure north, the beach is either absent or minimal until the stretch north of structures 4.7. The terrace and bluff conditions north of 4.7 are the same as those to the south. Profile 1, section 3/4 is typical of the conditions found in this stretch of section 4. North of the structures at 4.7 the beach widens and retains the characteristics of the beach to the south of structure 4.6. The toe of the terrace in this stretch is a medium-grained sand.

Reach 11B

North of the terraced area of reach 11 is a stretch of bluff which is subject to translational slides. This part of reach 11 extends from section 4.8, T.8N., north to section 33.8, T.9N. Land use in this area is entirely residential. A narrative of the conditions present is as follows.

T.8N., Section 3/4

At 4.8, the terrace terminates and the stratigraphy of the bluff becomes visible. The stratigraphy of the bluff can be divided into a lower lacustrine sequence from the toe of the bluff upward consists of 32 feet of silty clay; 7 feet of fine sand; 15 feet of medium sand; and 2 feet of sand and coarse gravel. The upper red-brown silty till unit is about 40 feet thick. The 35° slope is very unstable in this stretch with failure being translational movement of material down the bluff. A minor seep is present at the fine sand-silty clay contact. The vegetation cover is approximately 10% and the beach consists of 20 feet of medium grained sand.

T.9N., Section 33

The first stretch of section 33 extends from 33.0 north to 33.4. In this stretch the bluff height is approximately 90 feet and the stratigraphy varies somewhat from that described in section 3/4 (Profile 1, sec. 3). At the base of the bluff and extending 38 feet above the beach is a layer of lacustrine clayey silt. Over the clayey silt is a 5 foot thick unit of interbedded fine sand and silt, a 12 foot thick layer of medium-grained sand, and a 3 foot thick layer of gravel. Extending from the gravel to the top of the bluff is a 30 foot thick deposit of red-brown silty till. The slope angle is 40° on the upper part of the bluff where a scarp is located, and the slope angle is 30° from the base of the scarp to the toe. A major seep is located at the interbedded sand and silt - silt contact. Failure seems to be produced by the translational movement of the lacustrine material. The toe consists of clayey silt and slumped till which is easily eroded by wave action and further adds to the unstable nature of the bluff. The vegetative cover varies between 10 and 40% in this stretch because of the unstable nature of the bluff.

Beach width in the stretch between 33.0 and 33.4 varies between 15 and 25 feet and is comprised of a medium-grained sand with a band of pebbles and cobbles about 5 feet inward from the water's edge.

Structures in this stretch consist of two stone revetments (33.0 and 33.1) and two bulkheads (33.3 and 33.4). At 33.4 a deep ravine extends inward from the bluff (formed by a major stream).

The next stretch extends from 33.4 to 33.8. This stretch encompasses profiles 2 and 3. At profile 2 (33.5) the top of the bluff is composed of a red-brown clayey pebbly till. The extent of this till is unknown because of translational sliding. The toe of the bluff consists of slumped till. The bluff height at this location is 75 feet. The slope of the bluff in this stretch is 30° with the vegetative cover varying between 10 and 90%. No seeps were noted between 33.4 and 33.8.

The beach between 33.4 and 33.8 is greater than 25 feet wide. It consists mainly of medium-grained sand with a pebble and cobble zone extending from the water's edge inward approximately 10 to 15 feet.

In profile 3 (located at 33.8) the bluff height is 90 feet. At the base of the bluff is a 4 foot thick layer of gray clayey till. Over the clayey till is a 20' thick layer of interbedded sand and silt, and from the interbedded sand and silt to the bluff top is a red-brown silty till totaling 55 feet. Interrupting the red-brown till at a height of 36 feet is a 13 foot thick sand lens.

From 33.4 north to the end of the section bluff failure occurs as a series of translational slides. Also, surface flowage was noted, especially near the toe of the bluff.

Although no seeps were noted, the presence of horse tails indicates that seeps are present during periods of high recharge as in the spring.

Reach 11C

Part C of reach 11 is an area of extremely high bluffs that have an exceedingly fast recession rate. The stretch includes the shore between section 33.8 and section 28.5, T.9N. Land use in 11C is both parkland (Virmond Park) and residential. The conditions present in the sketch are as follows.

T.9N., Section 28

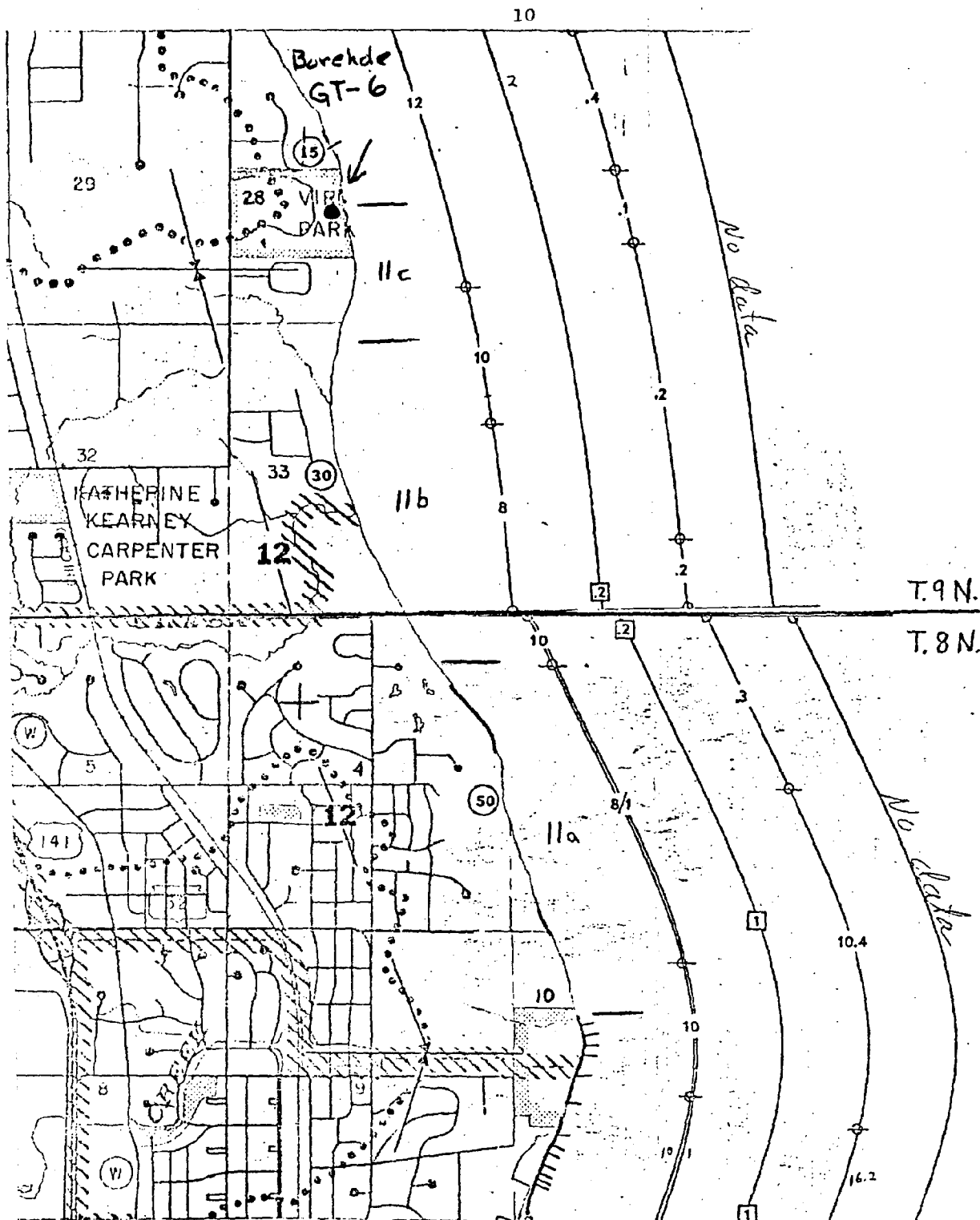
The part of this section that will be included in reach 11C extends from 28.0 to 28.5.

Bluff failure in this area is in the form of transitional slides on the lower half of the slope and a succession of shallow slumps on the upper slopes. The numerous slumps on the upper slopes give them a very hummocky appearance, whereas the lower slopes have a generally smooth exposed face. An 8 to 10 foot scarp is located continuously through the stretch at the bluff top.

The vegetative cover of reach 11C is highly variable. From 28.0 to 28.1 the bluff is about 100% vegetated, whereas north of 28.1 to 28.5 the cover ranges from 0% to 80%. In general, the vegetation was thicker on the upper slumped slope than in the lower slide areas. It should be noted that even the thickest vegetative cover has only a minimal effect toward stabilizing the bluff.

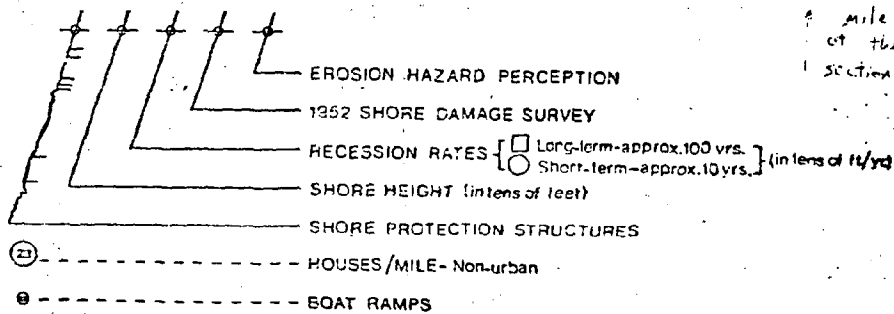
Very basically, the stratigraphy of this stretch includes interbedded silts, sands, and gravels in the lower half of the bluff and red-brown silty till making up the upper half of the bluff. The thick vegetative cover coupled with slumping on the upper slopes and a slide veneer on the lower slopes obscured any more accurate stratigraphy. No seeps were noted in this stretch.

The beach width in this stretch varies from 15 to 25' while the beach texture grades from cobbles and pebbles to the water's edge to a medium sand at the bluff toe.



Reach 11

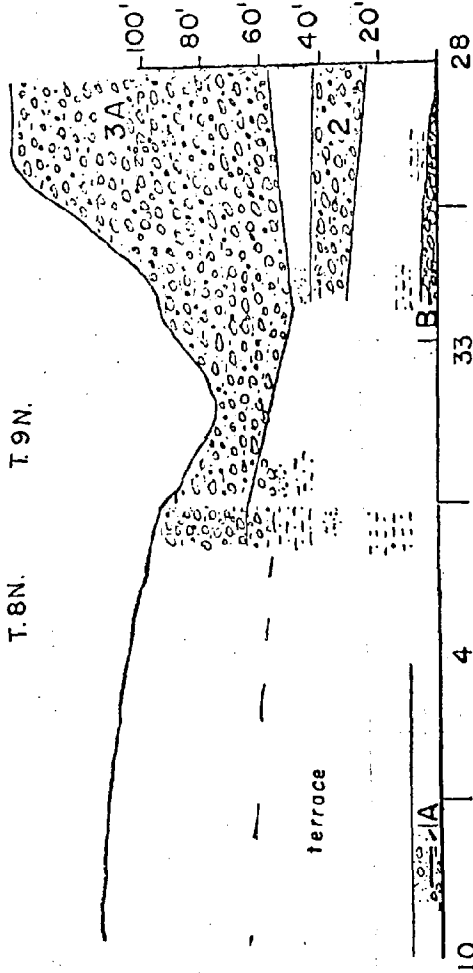
Scale 1:24,000



tenths of a
 mile north
 of the southern
 section line

Milwaukee Co., Ozaukee Co.

T.8N. T.9N.



LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

Generalized longitudinal section showing bluff stratigraphy in Reach 11. Numbers along base of diagram are geographic (1 mile) sections.

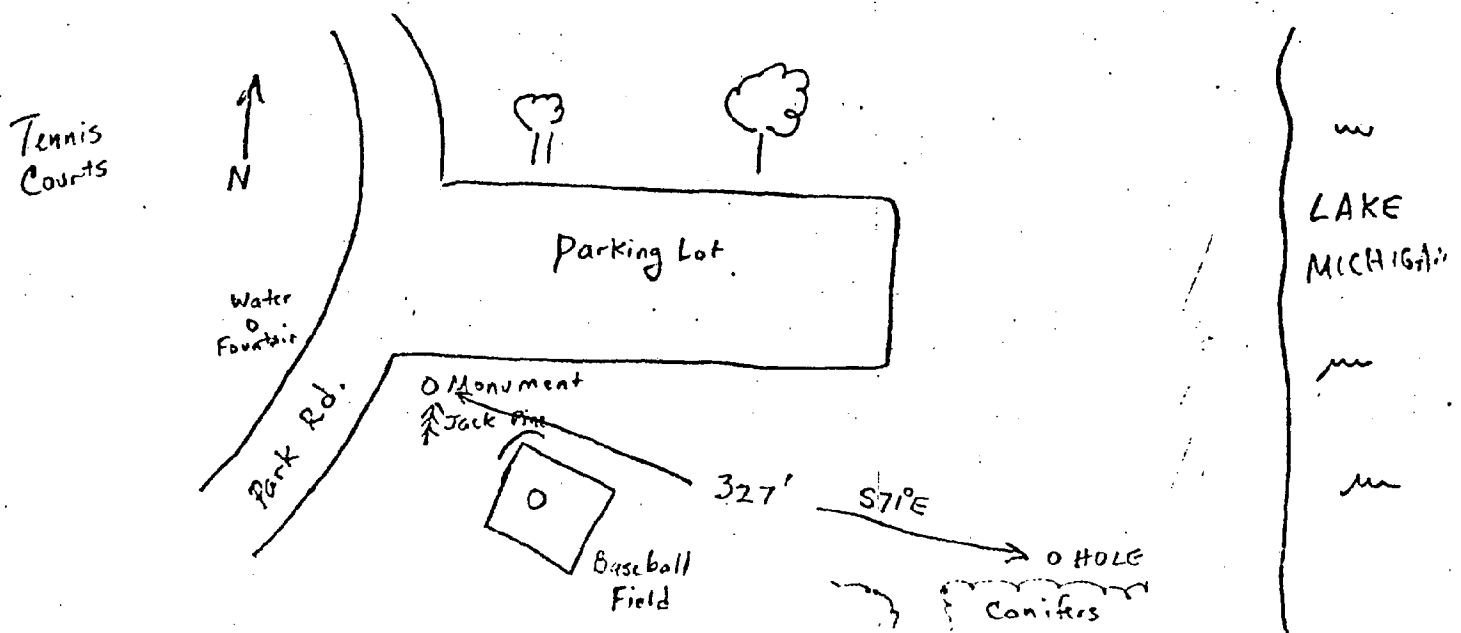
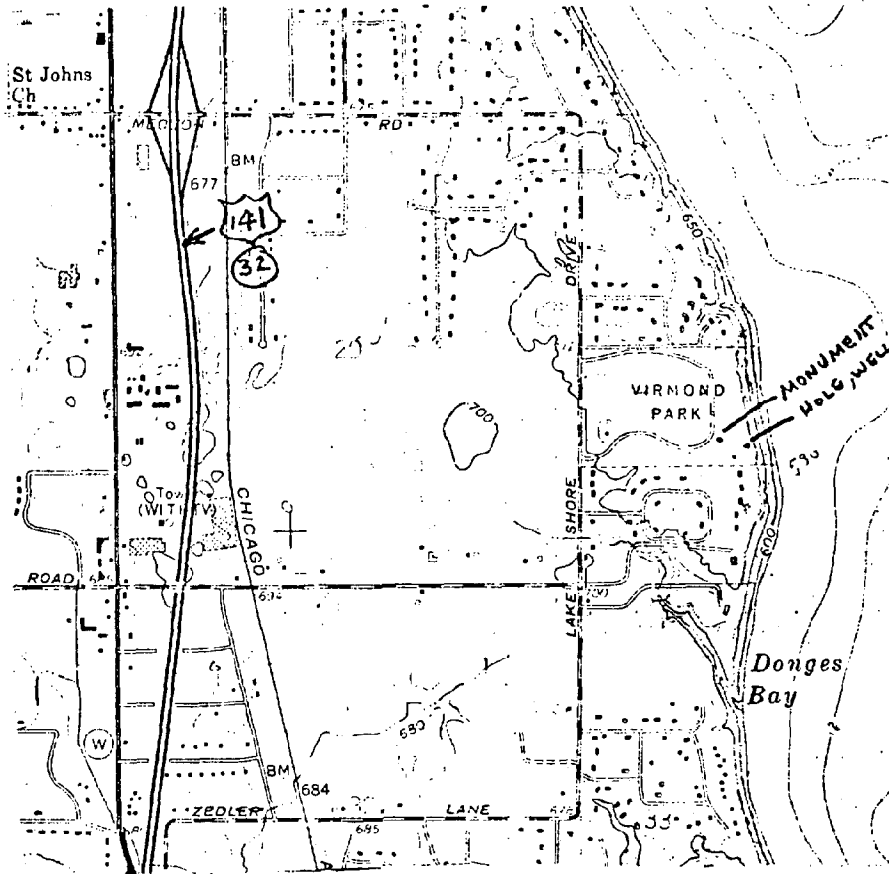
University of Wisconsin--Extension
Geological and Natural History Survey
1815 University Avenue, Madison, Wisconsin 53703

LOCATION AND MONUMENTATION SKETCHES

Boring No. GT-6 Virmond PK, Ozaukee Co.; Thiensville Quad.
NE 1/4 SW 1/4 / sec. 28 / T. 9 N. / R. 22 E.

Date

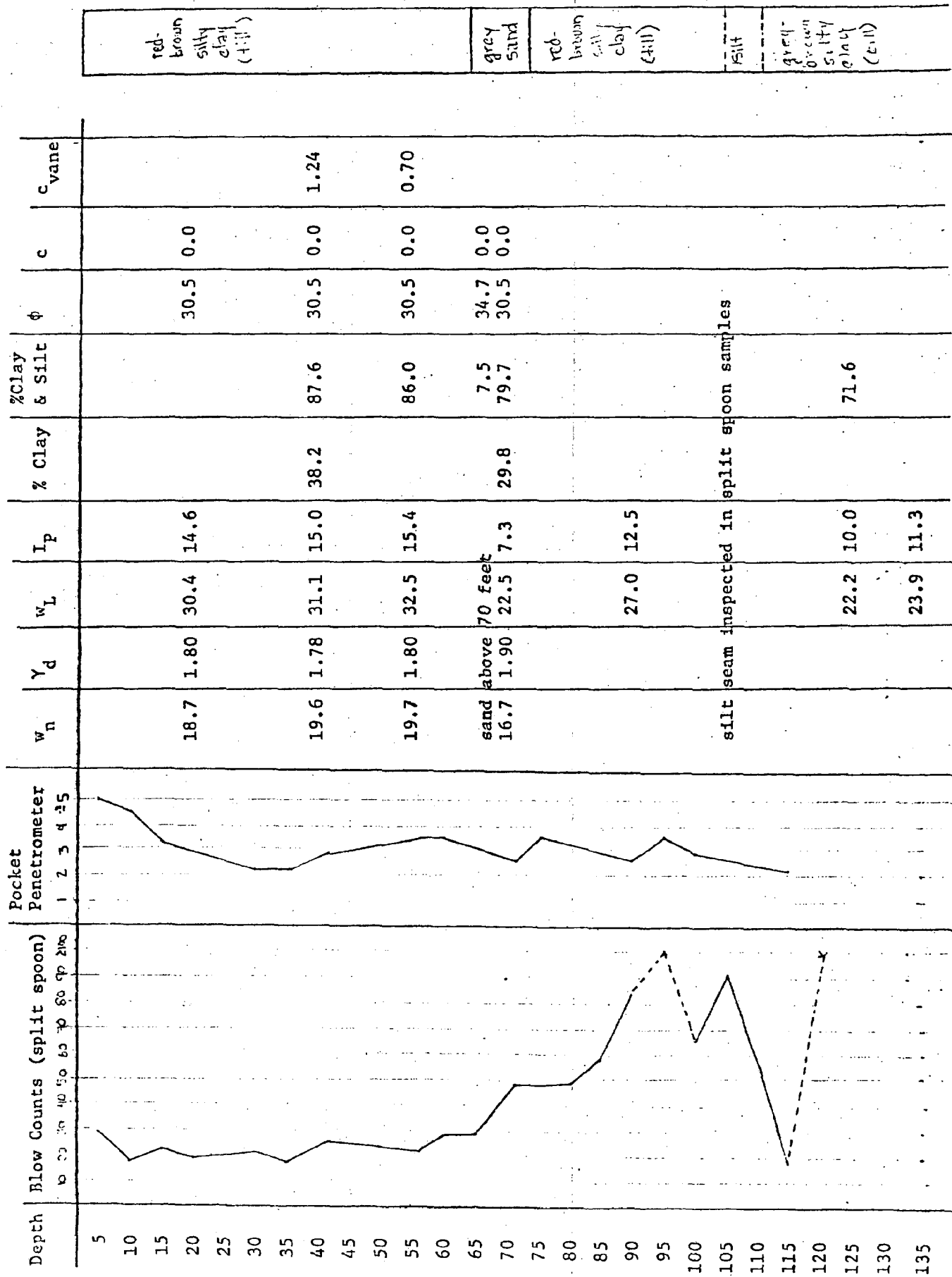
Drawn by

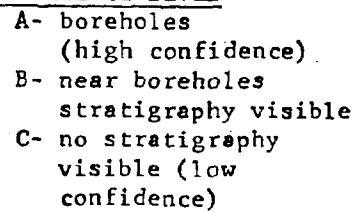


Borehole: GT-6

Location: Virmond Park, Ozaukee County, T9N, Sec. 28

13

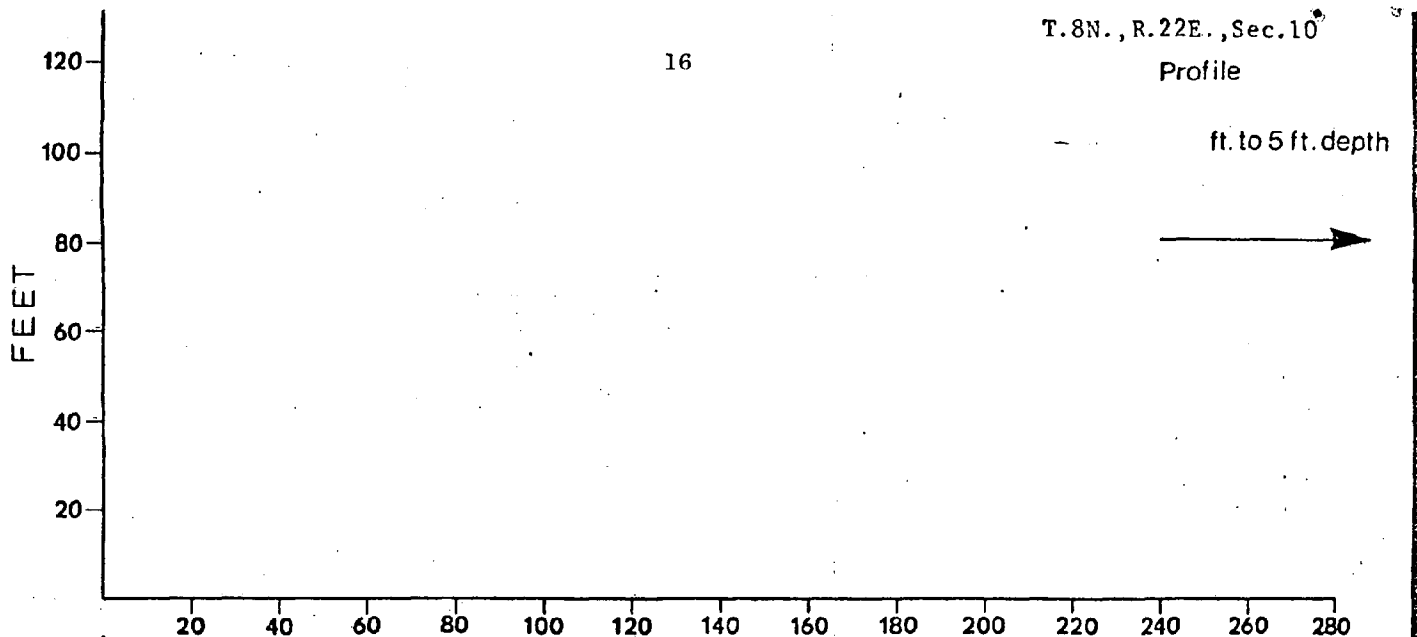




1. BLUFF	a-former lake terrace protects a bluff with approximately a 25° slope with 100% vegetation. No evidence of failure on the bluff.	b-No lake terrace, 100% vegetation on a stable bluff, 30° slope. Seawall to protect toe. no evidence of bluff failure.	c-Former lake terrace protects a bluff with approximately a 25° slope with 100% vegetation. No evidence of failure on the bluff.
2. TOE	a-toe material not visible due to shore structures and vegetation	b-sand	
3. BEACH	a- -30 ft. in the south grading to no beach in the north, composed of medium grained sand	b-no beach	c- -15 ft. medium grained sand
	d- +25 ft. medium grained sand		

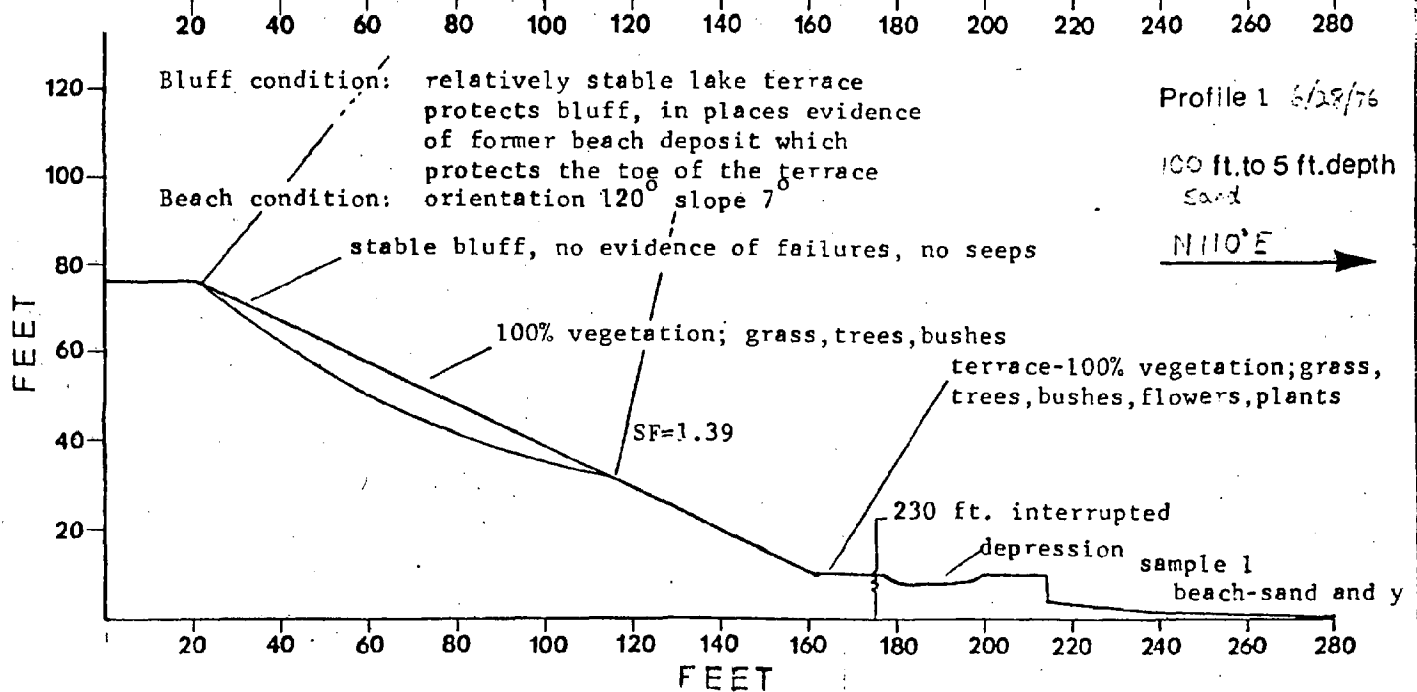
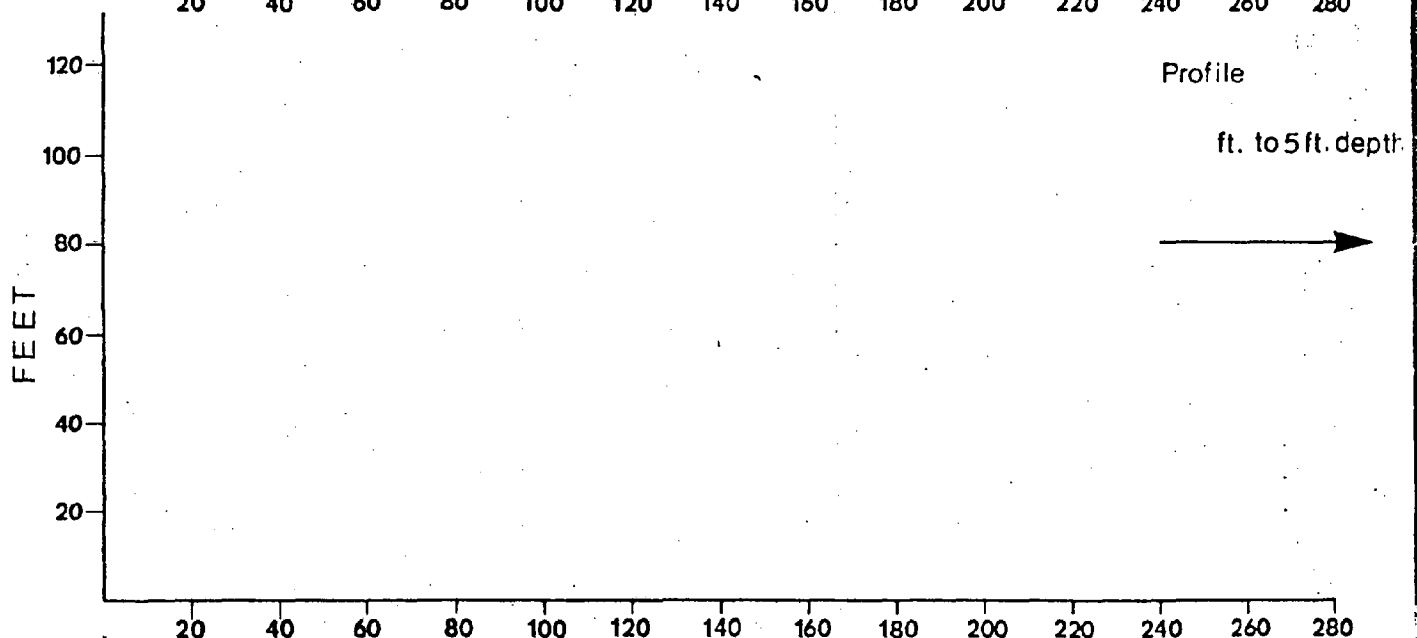
Profile

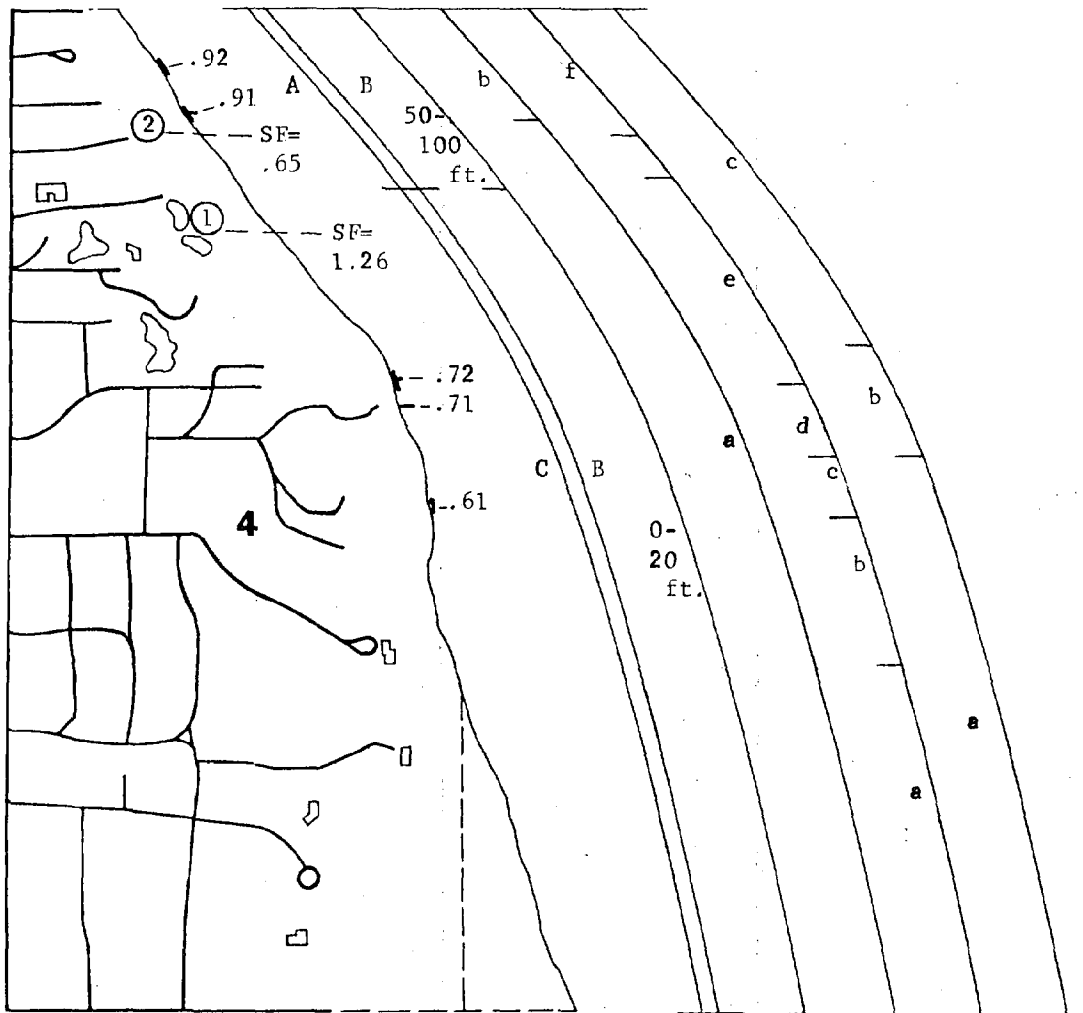
ft. to 5 ft. depth



Profile

ft. to 5 ft. depth





T.8N., R.22E.

SAFETY FACTOR
CONFIDENCE LEVEL

STABILITY LINE

BLUFF

TOE

BEACH

SAFETY FACTOR

A- less than 1.00

B- 1.00 to 1.25

C- greater than 1.25

CONFIDENCE LEVEL

A- boreholes

(high confidence)

B- near boreholes

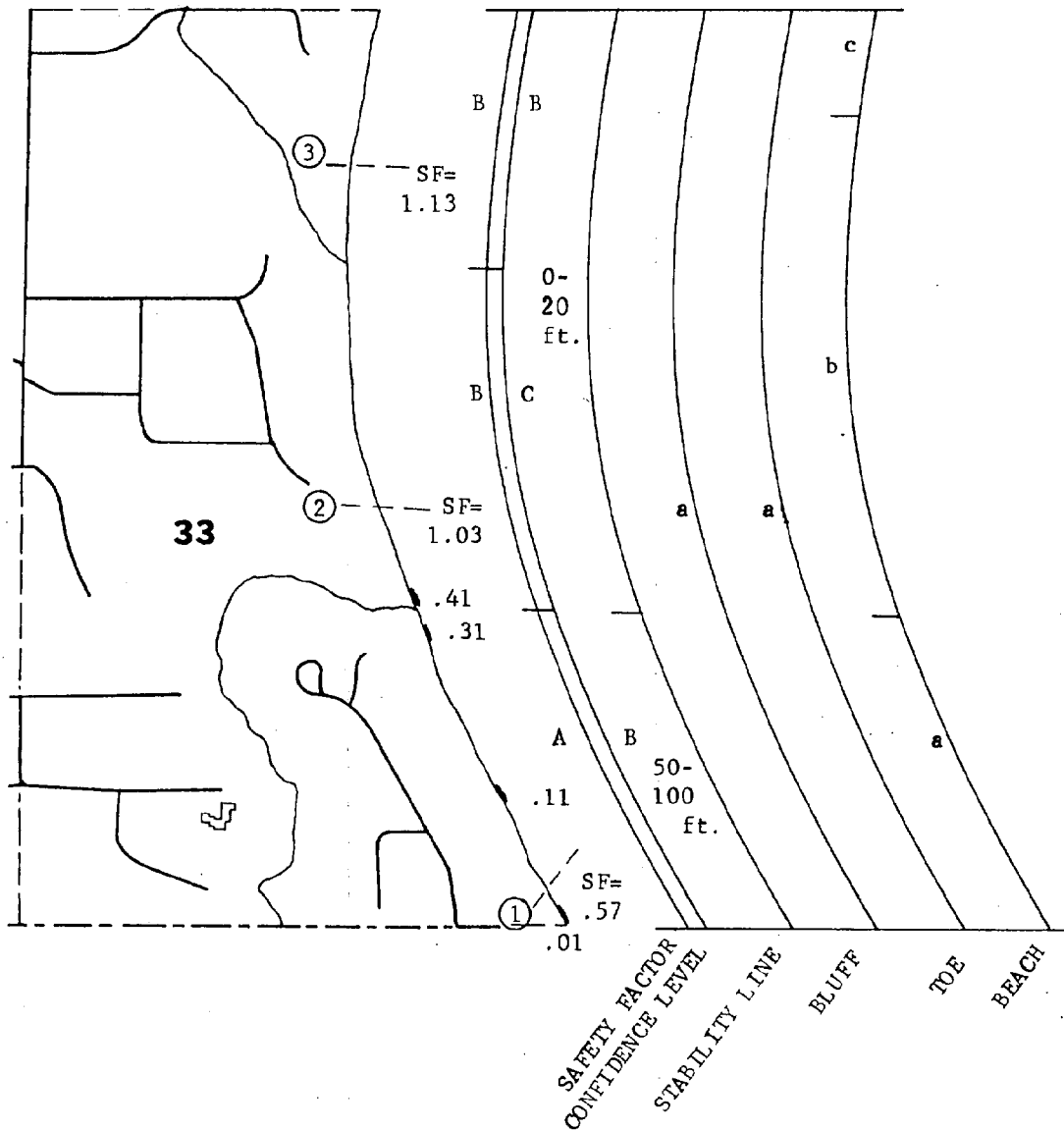
stratigraphy visible

C- no stratigraphy

visible (low

confidence)

1. BLUFF	a-lake terrace (100-300 ft. wide) protects a stable bluff. In places there is evidence of an old beach deposit which protects the toe of the terrace. 100% vegetation on the terrace which helps to stabilize it. The bluff is approximately 100 ft. high with a 30° slope. This seems to be stable with no slumps noticed. 100% vegetation was also observed on the bluff.			b-the bluff is in a highly unstable condition with lacustrine deposits composing most of the stratigraphy. Only a 20 ft. beach allows little protection of the toe. No terrace is found in this stretch. Bluff slope is 35° with only 10% vegetation.	
2. TOE	a-sand	b-2 ft. blue-gray silty, sandy, pebbly, cobbly, boulder till overlain by 4 ft. brownish gray clay, till overlain by a boulder train by 5 ft. medium sand.	c-sand	d-no stratigraphy	e-sand
	f-silt		g-silty clay		
3. BEACH	a- -25 ft. beach 1/2 being pebbles and cobbles from waters edge. 1/2 medium grained sand to the toe of the lake terrace		b-no beach	c-15-25 ft. beach medium grained sand	

SAFETY FACTOR

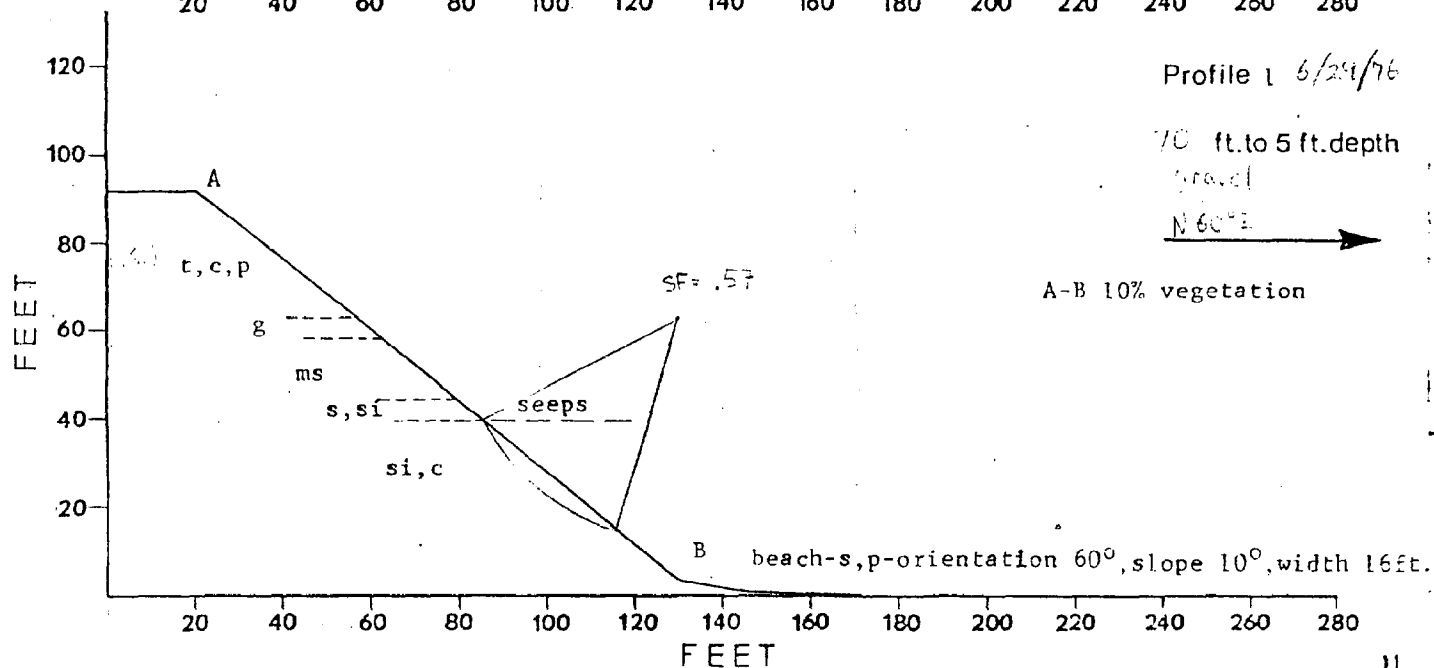
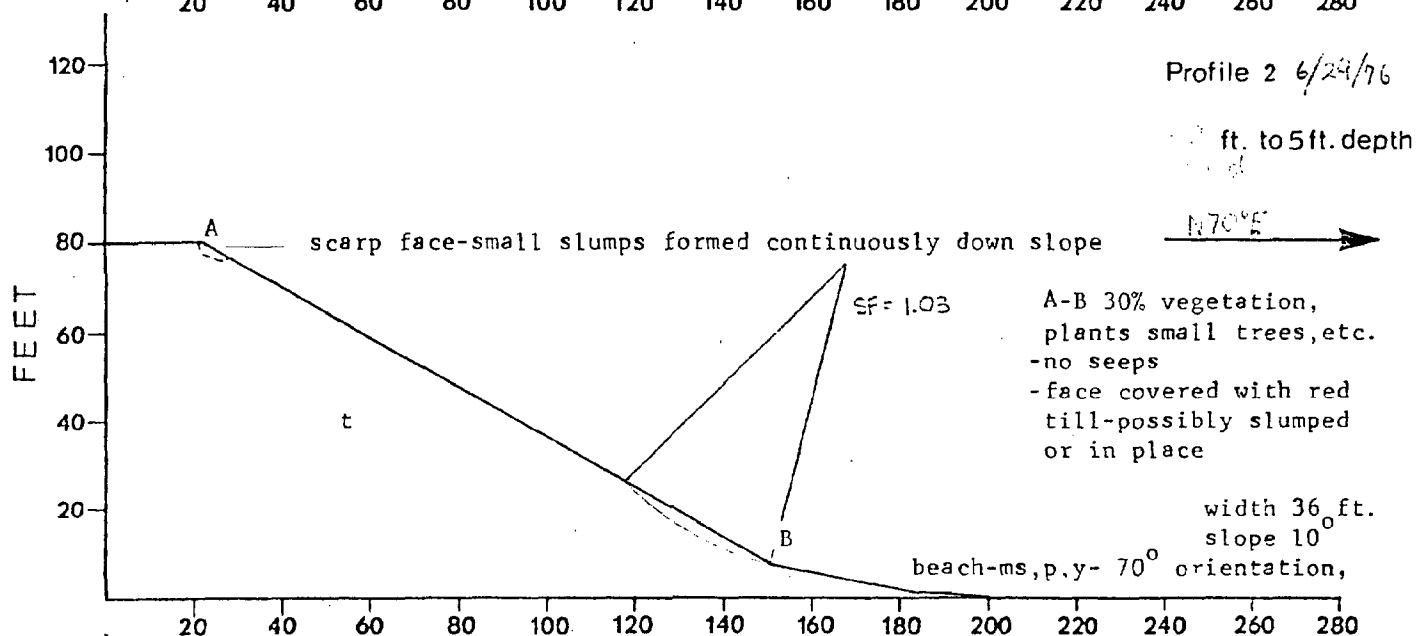
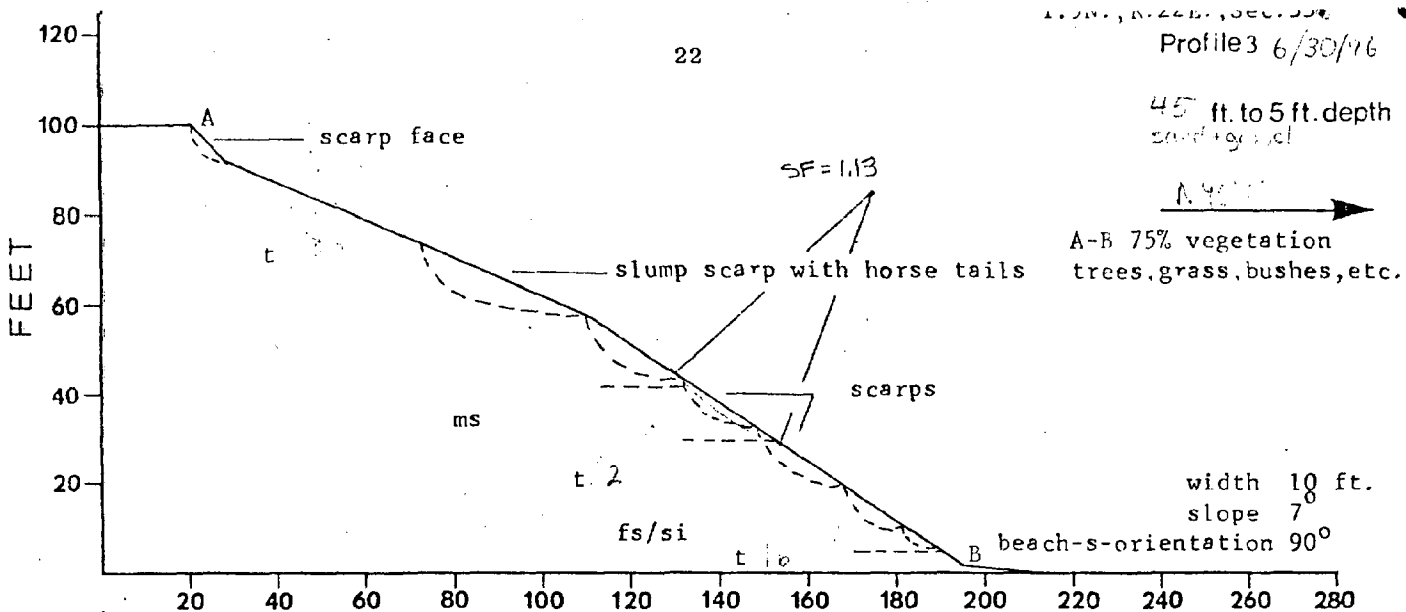
A- less than 1.00

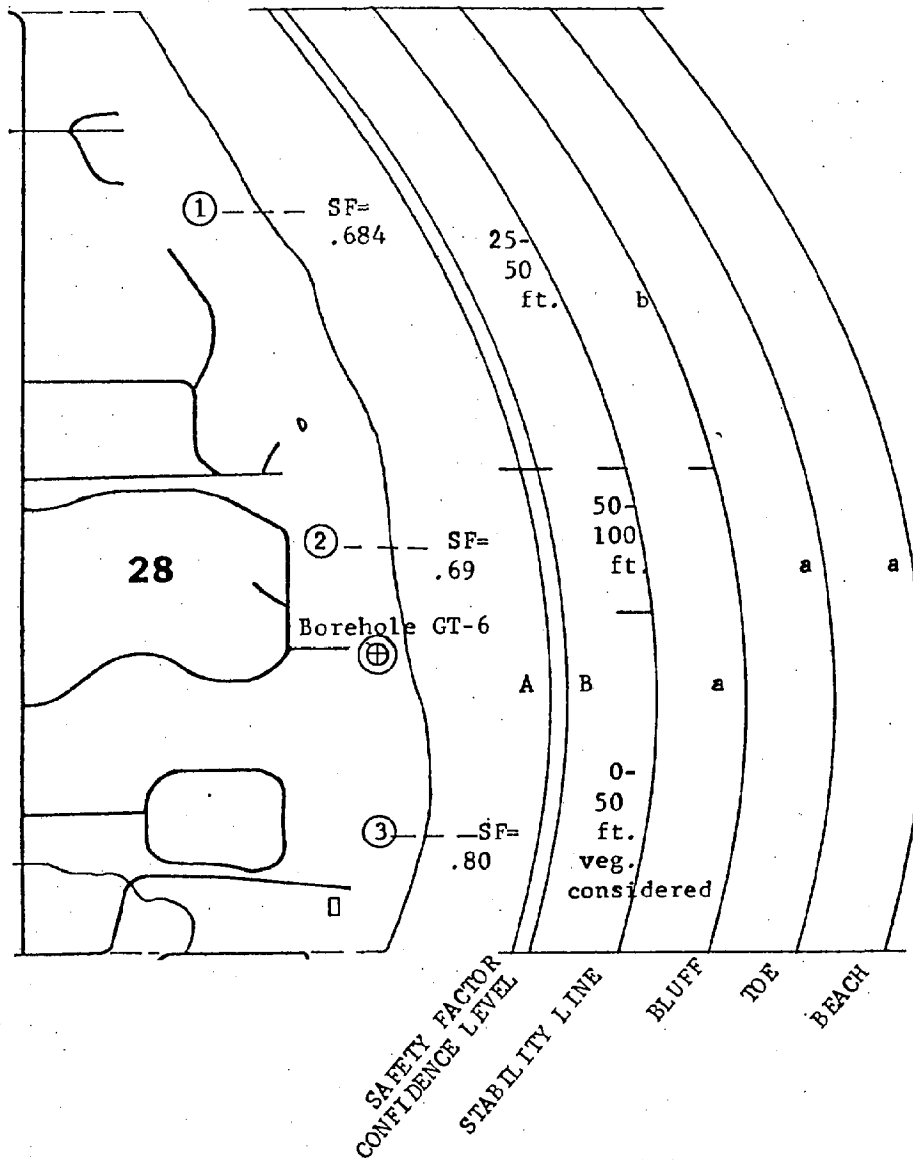
B- 1.00 to 1.25

C- greater than 1.25

CONFIDENCE LEVELA- boreholes
(high confidence)B- near boreholes
stratigraphy visibleC- no stratigraphy
visible
(low confidence)

1. BLUFF	a-bluff slope approximately 40° at top with a scarp face, 30° continuously down slope from bottom of scarp. Bluff seems to be a series of minor translational faults that are sliding downslope as the toe material becomes eroded by wave action. Vegetation ranges between 10% and 90%. Scarp at top of bluff continuous through the section regardless of vegetation.		
2. TOE	a-slumped till and vegetation continuously through the entire section.		
3. BEACH	a-15-25 ft. beach-medium grained sand from bluff toe to approximately 5 ft. from water's edge. 5 ft. of pebbles and cobbles at water's edge.	b- -25 ft. beach-medium grained sand from bluff toe to approximately 10-15 ft. from water's edge where pebbles and cobbles continue to water.	c- -10 ft. beach-medium sand, no pebbles or cobbles.



SAFETY FACTOR

- A- less than 1.00
- B- 1.00 to 1.25
- C- greater than 1.25

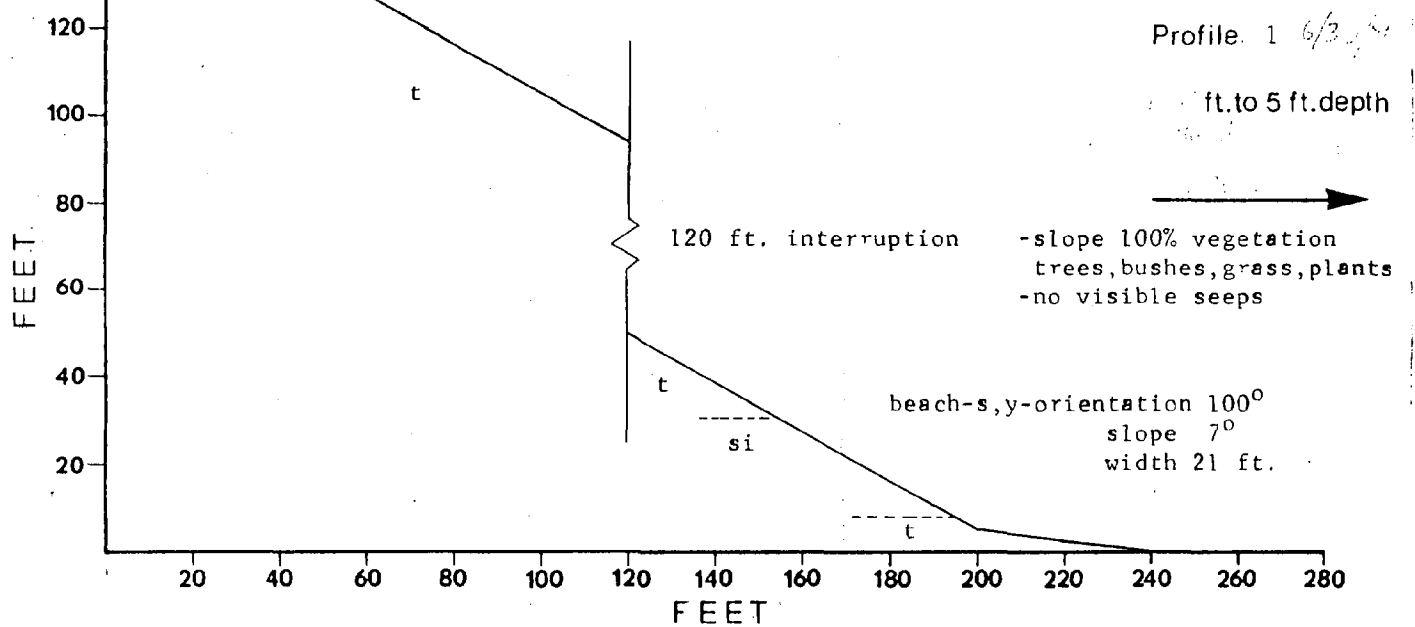
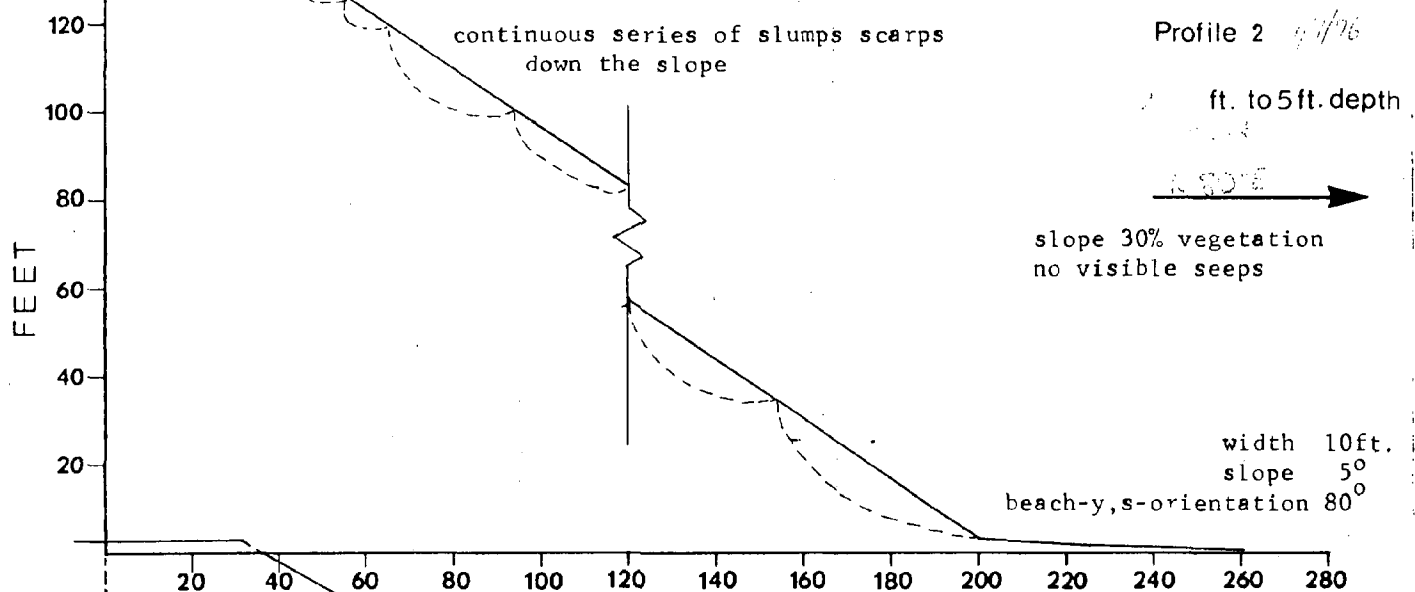
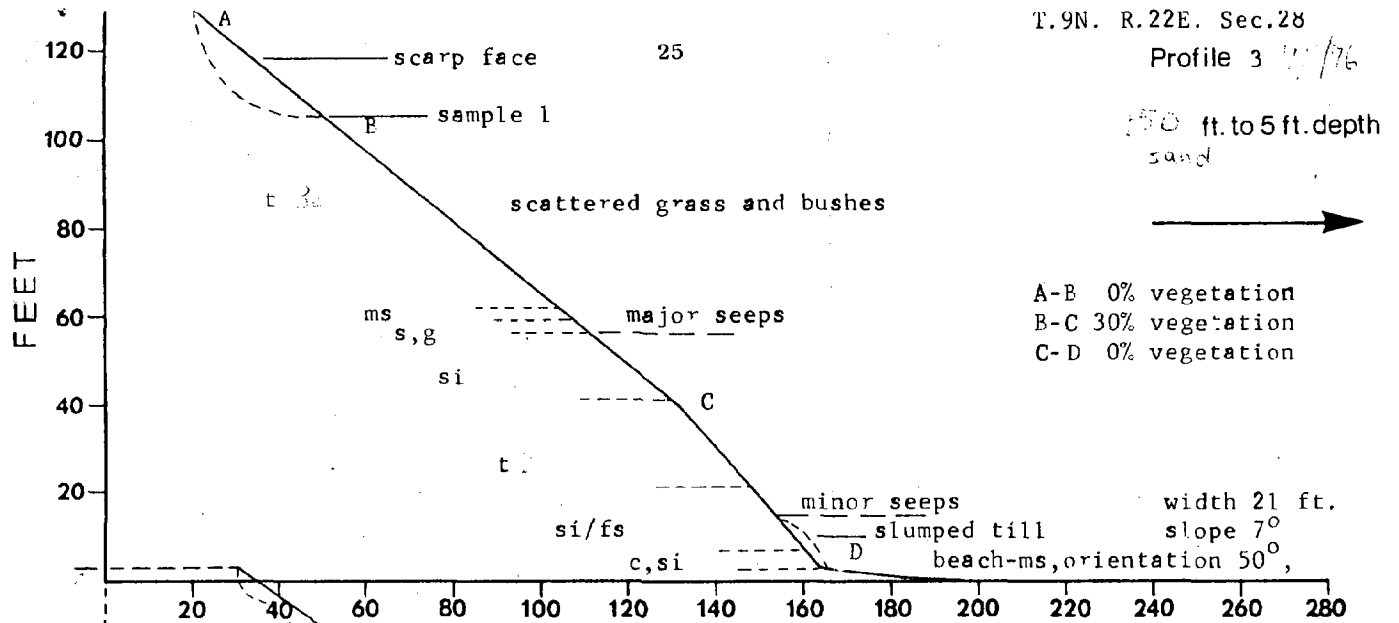
CONFIDENCE LEVEL

- A- boreholes (high confidence)
- B- near boreholes stratigraphy visible
- C- no stratigraphy visible (low confidence)

1. BLUFF	a-scarp face at the top of the bluff, translational movement (sliding, flowage and small slump blocks) all the way down the bluff face.	b-scarp face at the top of the bluff, small slumps continuously down the upper $\frac{1}{2}$ of the bluff along with translational movement. The lower $\frac{1}{2}$ consists of flowage, slump blocks and translational movement. The toe is being eroded by wave action.
2. TOE	a-slumped till covering in place silt and sand, in some places till.	
3. BEACH	a-15-25 ft.beach- pebbles and cobbles grading into medium grained sand at the toe of the bluff.	
4. STRUCTURES	- none	

T.9N. R.22E. Sec.28

Profile 3 4/7/76



Reach 12

Location

Reach 12 is located in Townships 9 N. and 10 N. in southern Ozaukee County. The reach is 6.6 miles long and extends from Virmond Park north to the northern section line of Sec. 28, T.10N. Land in this reach is used for residential purposes and as parkland.

Reasons for Criticality

Reach 12 is ranked 2nd on the Erosion Problem Area priority list with a Value per mile of 27. This high priority ranking is based on (1) the short term recession rates which range from 2 to 6 feet per 10 year period, (2) the Corps of Engineers, 1952 shore damage survey, (3) the very high bluffs present, and (4) the number of residences located on the bluff top. (up to 29 per mile).

General Conditions

Reach 12A

Reach 12 is divided into 2 parts on the basis of the bluff conditions present. The more southern part, Reach 12A, extends from the middle of section 28 T.9N. north to the middle of section 20 T.9N. Land use in this stretch is mostly residential.

The bluff conditions of 12A are high lighted by a very high bluff (up to 143 in Virmond Park) and extremely fast recession rates (many feet per year in Virmond Park). The slope failure type in this part of reach 12 is translational sliding.

The general stratigraphy of the area has a pair of glacial tills separated and underlain by several lacustrine silt, clay, and sand deposits.

The vegetation is partly dependent on the failure type. Where the slope has failed by sliding there is a very light cover if any. In areas of slump the bluff is more highly vegetated. There is however still a barren scarp and toe in the slump areas.

The beach conditions vary greatly and are best viewed on the section maps.

Section 28 T.9N.

The northern $\frac{1}{2}$ of section 28 is included in reach 12A. Land use in this section is for residential purposes and as park land. The conditions present are as follows.

The bluff height at the southern end of reach 12A is about 140 ft. The height decreases slightly through section 28 so that at the northern section line the height is 120 ft. The slopes in this section are failing by translational slides which are triggered by rapid erosion of the bluff toe. The topographic profile reveals a steep lower slope and a more gently sloping upper bluff face. These slopes give the bluff an average slope angle of 35° .

The stratigraphy of the bluff in the northern $\frac{1}{2}$ of section 28 includes 2' of red brown silty clay overlain by 16' of interbedded silt and fine sand. On top of these lacustrine deposits is 20' of red brown silty till and 2nd lacustrine sequence of 15' of brown silt, 3' of sand and gravel, and 3' of crossbedded medium sand. Over the second lacustrine series is a second red brown silty till layer which is over 50 ft. in thickness.

The vegetative cover on the bluff is variable but is usually between 15% and 40%. This vegetation has little or no effect in bluff stabilization.

The beach width in section 28 varies from 15' to 20' and the texture consists of pebbles and cobbles. The relatively narrow beaches fail to dissipate enough wave energy to protect the bluff toe.

Section 20, T.9N.

The section line which marks the southern boundary of section 20 runs along Mequon Road. The section can easily be divided in 3 parts for discussion purposes according to the bluff conditions present.

The most southern $\frac{1}{3}$ of section 20 is very uniform. From the section line north to 20.28 the beach is a constant 20 to 30 feet wide and made of sand with

a zone of gravel at the highest wave washed line. At 20.28 the width of the beach drops below 20 feet for a distance of .05 miles before again widening to greater than 20 feet. The bluff height is 100 feet at the southern section line and decreases northward to about 85 feet at 20.33. The slope is characterized by many small shallow translational slides and a vegetative cover (70% to 90%) consisting of weeds and small locust trees.

Profile 1 located at 20.09 is typical of the southern 1/3 of section 20. The bluff height is 102 feet and the beach is 30 feet wide. The exposure although very poor due to a veneer of slide debris and a vegetative covering of 70% gave the following stratigraphy: three feet of gray clay overlain by 6 feet of yellow buff medium sand and 93 feet of red-brown, silty-clayey till. Fifty feet to the south of profile 1 there is a two foot thick lens of silt found in the red brown till about 45 above lake level. The silt layer was marked by a small seep, however in the profile no silt is found and no seeps were observed. Except at the bluff top where a small scarp marks the bluff, the slope angle is 30°.

The central 1/3 of section 20 is very similar to the southern 1/3 with the exception that more slumps were noticed. From 20.33 to 20.67 the beach is between 20 and 30 feet wide and is composed of sand with a gravel zone located at the high wave washed line. The bluff height is about 80 feet and the vegetative cover varies from 50% to 100%. The characteristic failure type is a combination of slumping on the upper slopes and sliding on the lower slopes.

Profile 2 (20.43) was measured through this 1/3 of the section. In profile 2 the bluff is 78 feet high and the slope is 95% vegetated with weeds and very small locust trees. A slide parallel to the profile revealed the following stratigraphy: from the bluff toe to a height of 70 feet above lake level is a unit of red-brown, silty-clayey till, over which there is a 2 foot thick layer of silt and another 26 feet of red-brown, silty-clayey till. At the time the profile was drawn there were no seeps on this slope, but during periods of

higher rainfall seeps are located in the silt layer. The slope angle is 26° and the failure type is translational sliding. The beach width at profile 2 was 27' with the upper $\frac{1}{2}$ sand and the lower $\frac{1}{2}$ gravel.

North of profile 2 at 20.48 the slope is more stable and completely vegetated with large trees. This is the first such heavy tree cover north of Virmond Park. Beyond the more stable tree covered slope is another unstable area. At 20.55 the toe is being eroded and the lower slope is subject to slides whereas the upper slope is marked by slump blocks and scars. The stratigraphy at 20.55 also changes and a 4' thick lower brown-gray, clayey till is exposed. Separating the brown-gray till from the upper red brown till is a layer of interbedded silt and fine sand.

Reach 12B

The second part of reach 12 is an area of deep seated slumping punctuated by a few zones of translational slides. Throughout reach 12 there are large slump blocks resting at the base of the bluff and protecting the toe from further erosion. The time of failure for these blocks is not known but they appear to be several years old.

The stratigraphy of the bluff in this stretch has a lacustrine series of gray clay and interbedded silt and sand (up to 70 ft thick) exposed at the base. Over the lacustrines is the gray clayey till and the upper red brown silty till.

Land use in the stretch is for residential purposes.

Section 20 T.9N.

The northern $\frac{1}{3}$ of section 20 begins at a concrete seawall (20.65) which is the only structure of any consequence in this section. The seawall protects the bluff toe very well so the slope is stable and completely vegetated. The protected area is from 20.62 to 20.78. North of the seawall the slope profile changes so that the horizontal distance from the bluff toe to the bluff top is much greater giving a lower angle slope. Additionally the slope is broken by

many changes in slope. From the seawall north to the end of the section the beach is greater than 20 feet and has the characteristic upper half sand, lower half gravel composition.

Profile 3 at 20.86 is typical of the northern 1/3 of section 20. The bluff height is 82 feet, the beach is 25 feet wide (sand and gravel) and the slope is 100% vegetated with large trees. The eroded toe of the bluff exposes a red-brown, silty-clayey till which probably extends to the bluff top. The topographic profile reveals 6 major slope breaks which can be attributed to several large deep seated slumps. From profile 3 north to the end of the section the bluff regains the configuration of the southern 2/3's of section 20.

Land use of the bluff top in the southern 8/10 of the section is residential whereas the northern 2/10 is an unplanted field.

Section 17, T.9N.

The bluff top of section 17 is primarily residential. The only access to the bluff and beaches is through the yards of property owners or through the convent grounds at the northern end of the section.

The bluff of section 17 exhibits several different slope configurations and stabilities. From the southern section line (17.0) north to 17.13 the slope shows evidence of at least 2 major deep seated slump type failures. However these are very old failures and were detected only by the step like rise up the bluff. There are no barren scarps, as the stable slope, excluding the toe, is 100% vegetated by large trees and miscellaneous undergrowth. The factor which can distinguish this stretch from a terrace is the toe material, which is a red-brown silty till. There is not any sand covering the lower step. The beach below this zone of old slumps is greater than 25 feet wide and made of sand (upper half) and pebbles (lower half). The protection offered by the beach is not enough to stop the toe of slump block from being eroded. This zone and slope configuration is best viewed in profile 3 of section 20, T.9N.

North of 17.13 to 17.3 the slope is unstable and the major form of failure is translational sliding. This type of slope is shown in profile 1. The beach in this stretch of shore is greater than 20 feet wide and is made of $\frac{1}{2}$ sand and $\frac{1}{2}$ pebbles. The vegetative cover from 17.13 to 17.3 is about 20% to 60% (small trees and bushes).

At profile 1 (17.16) the bluff height is 96 feet. The topographic profile has no major breaks in slope--instead there is one long face inclined at about 28° with a few small scarps making the surface rough. At the top of the slope is a 2 foot near vertical scarp and at the toe there is a 1 foot vertical cut. The lower 36 feet of the bluff is composed of red-brown clayey-silty till with frequent pebbles and cobbles. Over this is a four foot thick layer of gray silty lacustrine clay and a 6 inch thick layer of very hard, very coarse, and angular gravel with a clay matrix. From the top of this unit (at 40 feet above the base) and extending to the bluff top is 55 feet of red brown clayey-silty till (again with frequent pebbles and cobbles). The vegetative cover is 60% (weeds) and the beach width is 25 feet at profile 1. There are no seeps on this slope.

North of the sliding zone is another zone of slumping. This zone extends from 17.3 to 18.5 and it is across this slope that profile 2 was drawn. As in the southern part of section 17 the slumping occurred long ago, and the slope is now completely vegetated, shows no barren scarps and is relatively stable. The topographic profile shows a steep (37°) toe which is being eroded by wave action. This face from D to C on the drawing is 10% vegetated by weeds. Above the toe from C to B is the terrace like surface of the slump block. The rotational movement along the fault is displayed by the negative slope (-7°) of this surface. Above the slump block is the true bluff slope, inclined at 25° . No stratigraphy was obtained because of the dense foliage and no seeps are present.

From the northern end of this slumping zone (17.5) to 17.7 is another zone of translational sliding. This stretch of bluff has profile a two part slope,

with the lower slope being very steep and unvegetated and the upper slope being more gentle and partially vegetated. This shape is caused by the rapid erosion of the toe and lower slope by wave action and the attempts of the upper slope to reach a stable configuration by sloughing off material in shallow translational slides. The beach in this stretch is about 20 feet wide north to 17.7 where it starts to narrow.

From 17.7 north to the northern end of the section there is a huge slump block making up the lower half of the bluff. The differences between this stretch and the other parts of section 17 are many. Most notably is the narrowing of the beach. At 17.7 the width dips below 20 feet and decreases rapidly to about 12 feet. At this point the texture is still half sand-half pebbles but north of 17.92 the width drops again and the composition changes to red brown till. The width for the remaining .08 miles is from 0. to 3 feet.

The remaining differences are best shown in profile 3. The topographic profile across the slump block reveals a much lower bluff, this being about 72 feet high. The slope is again in two large steps but the terrace-like first step instead of being just above the toe as it was previously, is 40 feet above the toe. The vegetative cover is lower and a barren scarp is present at the bluff top. The lower slope shows a steep wave cut toe and an area of slides just above it. Neither of these surfaces is vegetated.

The stratigraphy of profile 3 is also different in that at the base there is 5 feet of brown gray clayey till, overlain by 10 feet of red brown clayey silt, which is in turn overlain by 6 feet of brown gray silty clay and finally 59 feet of red brown silty till. The beach at the profile 3 location is 12' wide.

Not detected from the round but appearing on the air photos is a sand bar which runs the entire length of section 17.

T.9N., Sec. 8

The first stretch in section 8 extends from 8.0 to 8.5. The stratigraphy of the lower $\frac{1}{2}$ of the bluff in this section is not visible due to a large slump block at the base, however, exposed above the slump block is a unit of medium and coarse grained sands which grade into a fine sand higher in the bluff. Over the fine sand is 10' of clayey silt and 65' of red-brown clayey, pebbly till. This stratigraphy was obtained at the location of profile 1 (8.0) and can be highly variable to the north and south of the profile.

The southern end of the (8.0) consists of a large slump block at the base of the bluff and corresponding scarp at the top. The slump is seated in thick sand layer which is marked on the bluff face by a line of seepage. The toe material is the upper red brown silty till with some sand and gravel debris just above the beach. The vegetative cover on the slump is about 10% consisting mainly of horse tails.

North of 8.0 a large scarp is found at the bluff top through the entire section. From the lower extent of the major scarp a series of smaller scarps are found down the bluff. Until they reach the upper extent of a large slump block at the base of the bluff. This rotational slump block extends continuously through this stretch of coast. The slumping is a result of a saturated sand layer decreasing the strength of the material above, thereby allowing the material above to slide down the bluff. This failure was aided by wave erosion to the toe increasing the shear stress. The slope of the bluff above the slump block is approximately 30° . The seep which is visible near the upper limit of the fault block is evidence for the fact that there is a less permeable layer of material under the sand layer.

Vegetation on the bluff face in this section is highly variable. The upper scarp face is less than 10% covered. What vegetation is there consists of weeds and a few bushes. At the lower limit of this scarp the vegetative cover

increases to 100%. This cover consisting of trees, grass, and bushes continues across the top of the slump block. The face of the slump block which forms the toe of the bluff in this case, is void of vegetation.

The toe material consists of slumped sand, silt, gravel and till. The material is variable and can be one or a combination of the above materials depending on the location.

The second stretch in this section extends from 8.5 to 8.7. The stratigraphy in this section is not entirely visible but that which was found is located in a drainage channel located at 8.7. It consists of a gray clayey till at the base overlain by 30' of interbedded lacustrine silts and fine sands. Approximately 45' of red brown silty till forms the top $\frac{1}{2}$ of the bluff.

The slope of the bluff is approximately 25° with the exception of the upper scarp and on the face of the toe where it is 65° and 50° respectively.

The vegetative cover on the upper scarp is very sparse being 0% in most locations. This changes dramatically with the change in slope at the bottom of the scarp. Here it increases to between 80 and 100%. The vegetative cover consists primarily of bushes, grass, and trees. Further down the slope, the cover is 100% consisting of small trees, bushes, and grass. Again, the change in slope brings a dramatic decrease in vegetation. On the face of the toe, cover is 0%.

The toe material consists of slumped till. No seeps were found in this stretch.

The northern most stretch in section 8, extends from 8.7 to 5.0. The stratigraphy at the foot of the bluff, in this zone, is obscured by the slump debris. The first in place stratigraphy consists of about 5' of medium sand overlain by 10' of sand and gravel, 3' of interbedded silt and sand and 4' of red silt. This sequence is topped by 44' of red brown silty till.

The bluff is unstable, as series of small rotational slump blocks extend up the entire slope, Vegetative cover on the slope face is 100% with two exceptions. These are at the location of profile 4 where vegetation down most of the slope is 40% and on the face of the toe throughout the section where the vegetation is 0%. Where vegetation is located, it consists of trees, grass, weeds, and bushes. The slope of the bluff in this stretch is approximately 35° . No seeps were found except in the sandy silt lense in the red-brown till. A large drainage channel is located at the northern border of this stretch.

From 8.0 to 8.7 the beach is from 0' to 10' in width with pebbles and cobbles forming the lower $\frac{1}{2}$ and sand the upper $\frac{1}{2}$. From 8.7 north to the end of the section the beach increases in width (from 15' to 25') and the texture remains pebbles and cobbles and $\frac{1}{2}$ sand.

T.9N., Sec.5

Section 5 is easily divided into 5 parts, for descriptive purposes. The southern part; (5.0 north to 5.2); the central part (5.3 to 5.5); and the northern part (5.65 to the end of the section) are zones of deep seated slumping. Interrupting these zones are two areas of translational slides.

Profile 1 (5.25) is drawn through the southern slide area. The topographic profile of the bluff in this area has a steep lower slope and a more gentle upper slope.

The stratigraphy at this location consists of fine grained lacustrine sand and silt at the base of the bluff overlain by generally coarser grained lacustrines. The coarse grained sequence consists of 10' of medium sand; 5' of sand and gravel; 15' of crossbedded sands; 2' of gravel, and 3' of silt. Over the lacustrine deposits is a 45' thick layer of red brown silty till. It should be noted that the lower 5' to 10' of the till is reduced to a light gray.

Profile 2 is drawn through the northern area of slides and displays similar (but generally finer grained-silts in place of sand-sand in place of

gravel) stratigraphy. In addition to being finer grained a gray clayey pebbly till is present at the base of the bluff in Profile 2. The contact between the overlying lacustrine sands and clayey till is marked by a major seep.

The beach at both the profile is about 20' wide.

The vegetative cover in both slide areas is about 10% to 20%.

The zones of slumping are very similar to those discussed earlier in this reach. In each case there is a 1) rapidly eroding, steep, and unvegetated toe, 2) an almost level and heavily vegetated slump block surface and 3) a steep partially vegetated scarp above the slump block. The stratigraphy in the zones of slump is obscured by the slump block and the vegetative cover. The beaches in the slumped areas are from 5' to 25' wide and usually are sand and pebbles.

The bluff at the northern end of the section (5.9 to the end of the section) is extremely stable.

Section 33, T.10N.

Land use in this section is primarily residential. Best access to the bluff and beaches is through the fields between homes. The section contains both translational sliding and rotational slump type failures.

From 33.0 to 33.28 the failure type is slumping. Throughout this distance a large slump block occupies the lower half of the bluff. This can be seen in profile 1 which was measured across the block and up the bluff at 33.12. In the drawing there is a steep unvegetated toe despite the 37' wide sand and pebble beach. Above the toe is a long gentle rise which constitutes the surface of the slump block. This surface is highly vegetated (100%) with trees, bushes, and weeds. Above the slump block is the true bluff and the scarp left by the failure. This slope is inclined at 32° and is only 25% vegetated (weeds). The only visible stratigraphy was on the barren scarp face. This revealed at least 30 feet of red-brown silty till. No seeps were located in this profile. All evidence pointed to the fact that this failure was old and that the bluff is relatively immune from further slumping in the near future. At this time the

fastest erosion is occurring on the toe of the slump block which is exposed to wave action.

The wide beach at profile 1 does not continue for the length of the slumping zone. At 33.2 the width drops to less than 20' and more of the wave energy is directed on the toe.

Directly north of the slumping zone the narrowing of the beach causes very major slides. This zone extends north from 33.29 to 33.42. A characteristic slope of this stretch is shown in profile 2 (33.75). Here the beach is a narrow 7 feet and consequently the bluff toe is being rapidly eroded. At the time the profile was drawn the toe was a large wedge of slide debris (BD on the drawing). Above the slide debris is a 40° slope without any breaks. The light (15%) vegetative cover allowed a good stratigraphic section to be recorded. The first in-place stratigraphic is located 33 feet above the beach. This first unit is a 13 foot thick layer of massive silt with a small amount of interbedded fine sand. Over this is a 12 foot thick layer of interbedded silt and sand, which is overlain by 15 feet of gray clayey till. Over the gray clayey till is 4 feet of interbedded silt and fine sand and 12 feet of coarse sand with interbedded silt. The remaining 24½ feet of the 128 foot bluff is made of a red brown silty till.

Seeps are present at the base of the permeable coarse sand and silt. These seeps are in part responsible for the severity of the erosion in this zone.

North of the slide area is another zone of slumping. This zone extends from 33.42 north to 33.9 and is very similar to the southern slump zone of this section. There is an unvegetated, eroding, and steep toe followed by an almost level highly vegetated surface of the slump block. Rising from the slump block is the steep bluff slope. The beach along the foot of the bluff in this zone is greater than 20 feet wide from 33.41 to 33.77, and less than 20' wide north of 33.77. The toe material along this entire stretch is slumped red brown silty till. A large ravine dissects the bluff at 33.72.

From 33.90 to 33.99 a stretch of translational slides exists. This erosional situation can be directly tied to the narrow beaches which expose the toe of the bluff to the waves. Profile 3 exemplifies the conditions present in this zone.

In profile 3 the slope shows the standard slide configuration with the modification of a mound of slide debris covering the toe. (This mound, CE on the drawing, will probably be quickly removed.) The normal steep lower slope of slides is represented by the slope segment BC and the more gentle upper slope is represented by the AB slope segment.

The stratigraphy of the profile 3 location (33.95) has the same units as does profile 2 exposed slightly lower in the bluff. In profile 3 a layer of interbedded fine sand and silt 14 feet thick is located 36 feet above the beach. Over this layer is the gray clayey till which in profile 3 is 25 feet thick, 10 feet thicker than it is in profile 2. Over the gray clayey till is a sand and gravel layer 11 feet thick and 31 feet of red-brown silty till, making the height of the bluff at this location 117 feet. Two seeps are located on the bluff, one in the lower interbedded fine sand and silt and one at the base of the upper sand and gravel unit.

The conditions present at the end of section 33 change from a sliding zone to a slumping zone. This 200 foot stretch has a configuration similar to that of the southern two zones of slump in this section.

Section 28, T.10N.

The bluff top in section 28 is used as both residential land and farm land. The only access to the bluffs and beaches is through the fields or yards of the property owners. The slope conditions present in section 28 alternate between recent slides and old slumps.

The southern 300 feet of the section is an area of slumping. Although this failure is relatively minor it still exhibits the characteristic form of a slump zone. There is a narrow (5 feet) beach, a steep eroding toe of the slump block,

an almost horizontal slump block surface, and the steep scarp behind the block.

Directly north of this slumping zone is a drainage channel which cuts very deeply into the bluff. (Channel located at 28.75, visible on photo 1.) North of the ravine is a major slide area, extending from 28.7 to 28.24. Profile 1 measured across this area is characteristic of the sliding present. (Profile 1 measured at 28.15). In profile 1 a relatively wide beach (30 feet) fails to give adequate toe protection. This failure is probably due to the low slope angle of the beach (7°) which allows the waves to run far up the beach.

The topographic profile has a long 43° lower slope. The first break occurs 86 feet above the toe. Here the inclination is slightly lower being about 32° . There is then a steep (51°) scarp extending to the bluff top. The height of the bluff is 126 feet and the vegetative covering is 5% on the lower slope (CD on drawing) and 20% at the upper slopes AB & BC). The slight depression formed on the upper slope from A to C is the seat of the slide. Material torn from this depression and then slides down the steep lower slope and partially covers the toe.

The steepness of the bluff and the corresponding lack of vegetation allowed a good stratigraphic column to be recorded for this location. Exposed at the base of the bluff and extending 8 feet above the base is a deposit of gray laminated lacustrine clay. Over this is a 68 foot thick layer of interbedded sand and silt, which is broken 32 feet above the toe by a 4 foot thick layer of pure silt. Above the interbedded sand and silt at a height above the toe of 83 feet is a 9 foot thick layer of gray silty clayey till. The location of this till corresponds to the lowest break in slope on the topographic profile. It seems that this is the resistant basement above which the slides debris were torn free. Straigraphically above the gray clayey till there is 26 feet of red brown silty till (no lacustrines separating the two tills) which is overlain by 6 feet of stratified (rhymited) clay and 5 feet of sand and gravel. At the very top of the bluff between the sand and gravel and the soil is a thin layer of loess.

This stratigraphic column varies significantly from that recorded at the northern end of section 33 (in profile 3). Although the toe of profile 3, section 33, was covered it seems that the lower interbedded sand and silt layer is as much as twice as thick in this profile. This extra thickness causes the gray clay till to be exposed 30 feet higher in the bluff and to be 16 feet thinner (only 9 instead of 25). This extra height is also probably responsible for the lack of any lacustrine deposits separating the two tills. (The glacier which deposited the red brown till scraped off any lacustrines.) Of special interest in this column is the presence of water laid deposits so high in the bluff, high with respect to both elevation and stratigraphy. This is the only location discovered in Ozaukee Co. or northern Milwaukee where water laid deposits are over the red brown silty till. The origin of these sediments is either fluvial (by outwash streams) or lacustrine (in ponded waters).

Seeps are located in this profile in the interbedded sand and silt just above the less permeable silty layer. (16 feet above the beach). These seeps do not add significantly to the erosion problem.

North of the slide area just discussed is a zone of slump which extends from 28.24 to 28.74. This area has the typical slump failure form. The beaches along this stretch are for most of the distance 5 to 20 feet wide and about half sand and half pebbles. In this area of shore the upper part of the beach is fine grained while the lower part of the beach is much coarser material. The only part of this stretch that has a beach wider than 20 feet is from 28.42 to 28.52 and at 38.33. In both of those places streams enter the lake carrying large amounts of sand eroded from their deeply cut channels. The single structure in section 28 is located in this stretch. It is a concrete drainage sluice running from the bluff top down to the water at 28.59.

Profile 2 drawn at 28.60 is typical of large slump regions. The beach is 18 feet wide, there is a steep 6 foot toe and then a gently sloping heavily wooded section (D to F on drawing), that represents the surface of the slump block. Behind the slump block there is a steep scarp (48°) rising to the bluff top. The bluff height in profile 2 is 124' and the vegetative cover varies from 0% at the toe and 10% on the scarp to 100% on the slump block surface. The only visible stratigraphy is the upper red brown till which is at least 20 feet thick at this location.

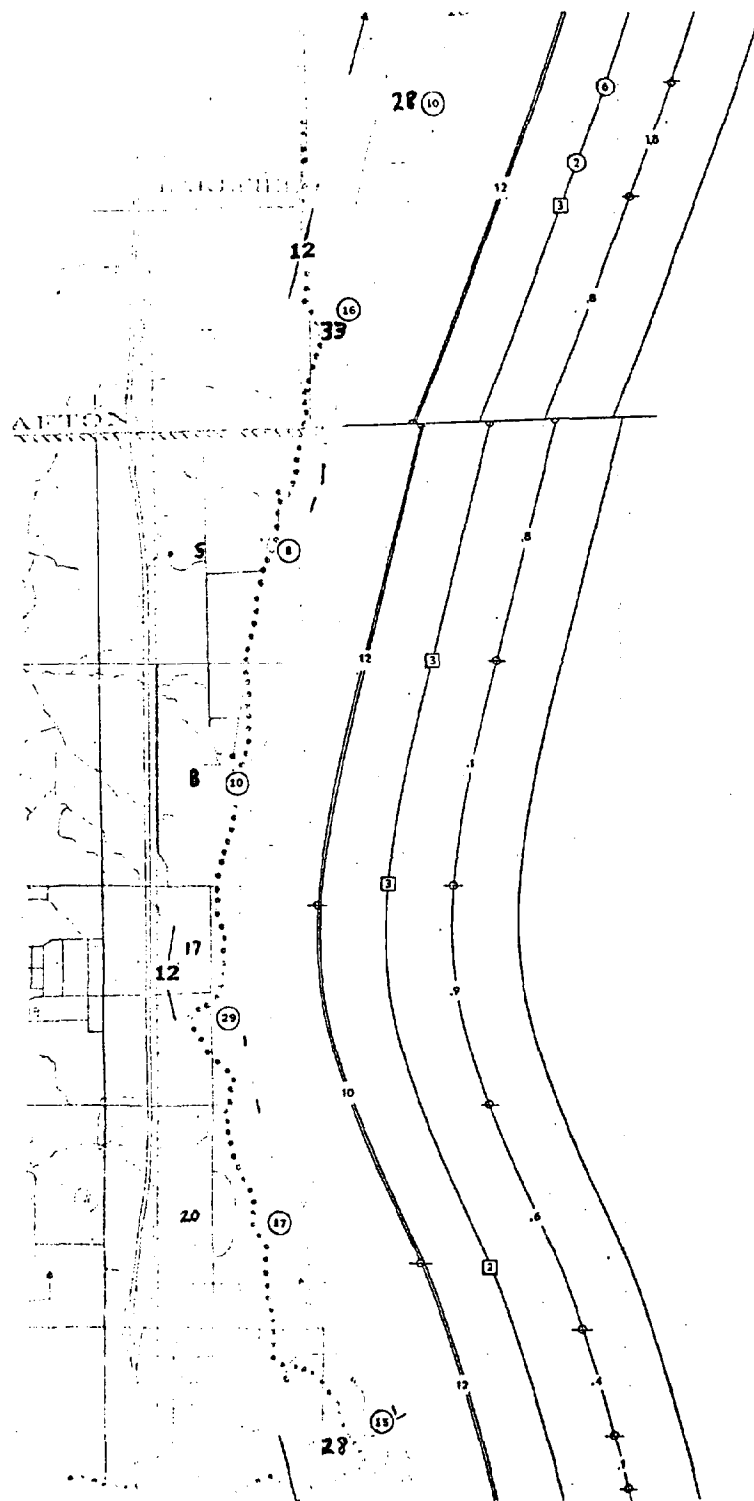
North of the central slumping zone of section 28 is a zone of severe slides. This area extends from 28.74 to 28.95. The beaches which are very narrow (on the lower side of 5 to 20 feet) are responsible for the severity of the erosion. The bluff along this stretch is very similar to that portrayed in profile 3 (28.8).

The topographic profile at this location has a slightly concave shape, which is due to the mass of slide debris which forms the toe. (E to C on the drawing.) Above the debris pile is a long straight slope, inclined at 40° . Above this is a steeper 45° face which extends to the bluff top. The bluff at the profile 3 location is lower than the other profiles in section 28, its height being 110'.

The stratigraphy exposed is as follows. At the base of the bluff is 6 feet of laminated gray pebbly lacustrine clay. Over this is 4 feet of medium sand. The contact between these two layers marks a line of seepage. Overlying the medium sand is a layer of interbedded fine sand and silt 21 feet thick, and a deposit of gray clayey till (with many shale pebbles) 5 feet thick. Lying in contact with the gray clayey till is 54 feet of red brown silty till. The one true break in slope (at B) is not related specifically to any one stratigraphic change.

Near to the northern section line a stream flows north almost parallel to the lake. Consequently there is a deep channel cut (parallel to the shore) which leaves a very sharp ridge or backbone structure. This is readily visible in photo 27.

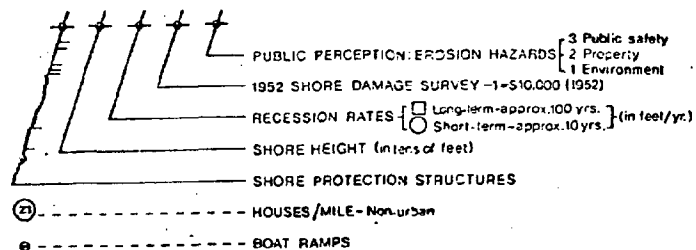
The northern section line cut across an area of old slump blocks like those discussed previously in this section.



Reach 12

1 mile

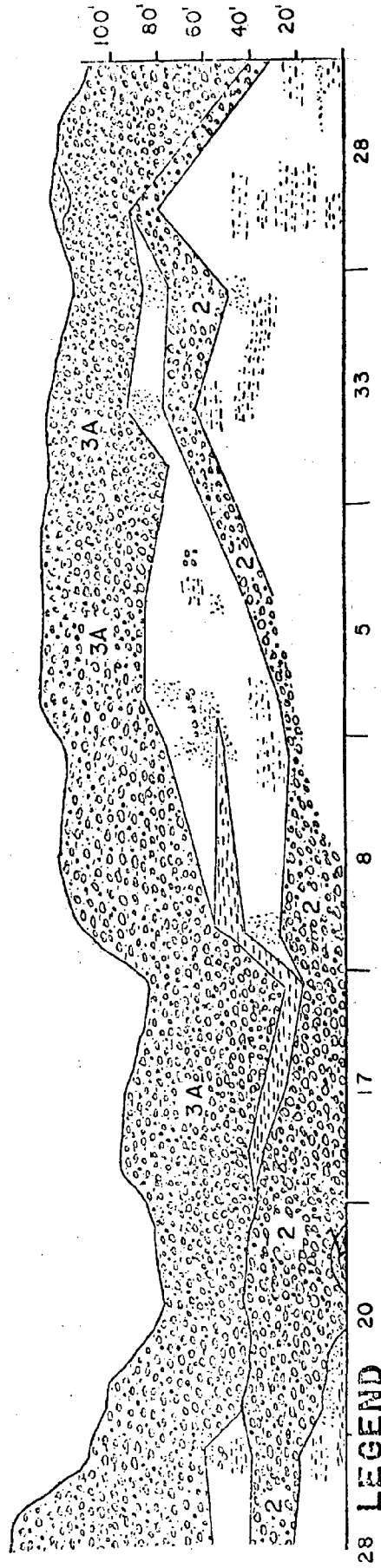
N












T. 9 N.

T. 10 N.

Ozaukee Co.



28 LEGEND 20

- | | | | | | |
|---|-----------------|---|-------------------------|---|-------------------------|
|  | SAND |  | SILT |  | COVERED OR INACCESSIBLE |
|  | GRAVEL |  | CLAY |  | TILL |
|  | SAND AND GRAVEL |  | CLAYEY SILT, SILTY CLAY |  | MIXED SEDIMENTS |

Generalized longitudinal section showing bluff stratigraphy in Reach 12. Numbers along base of diagram are geographic (1 mile) sections.

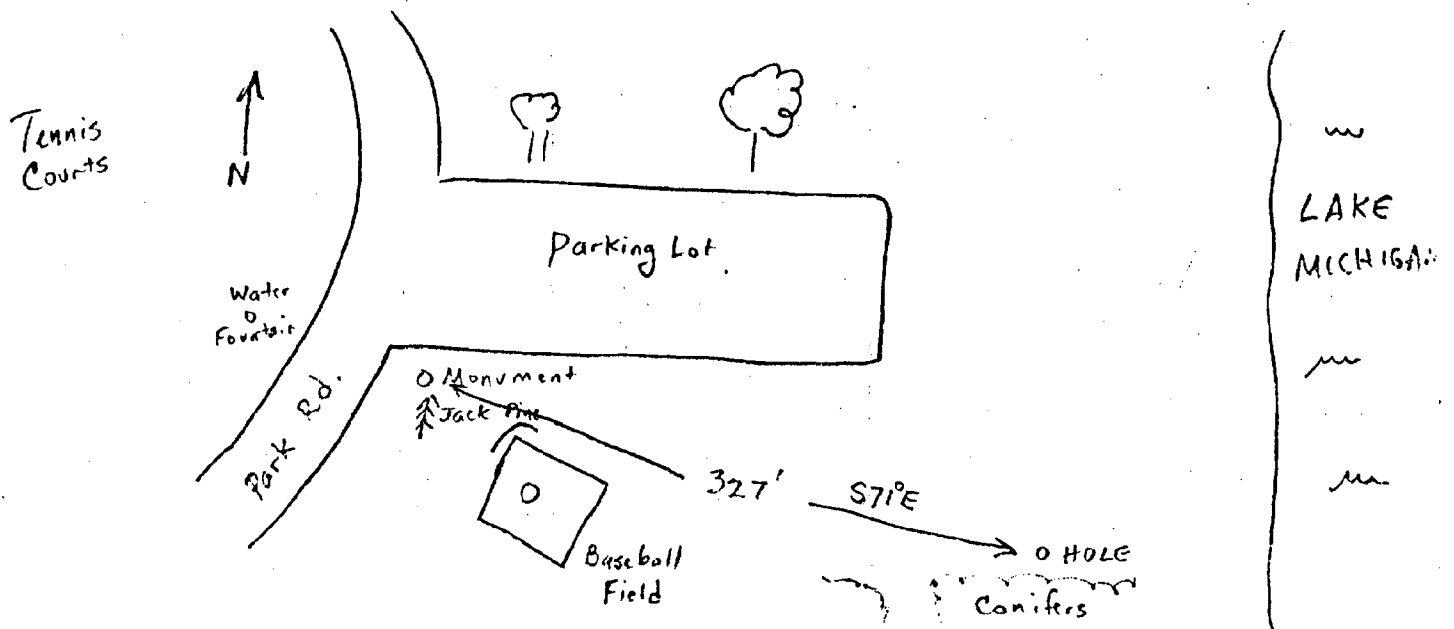
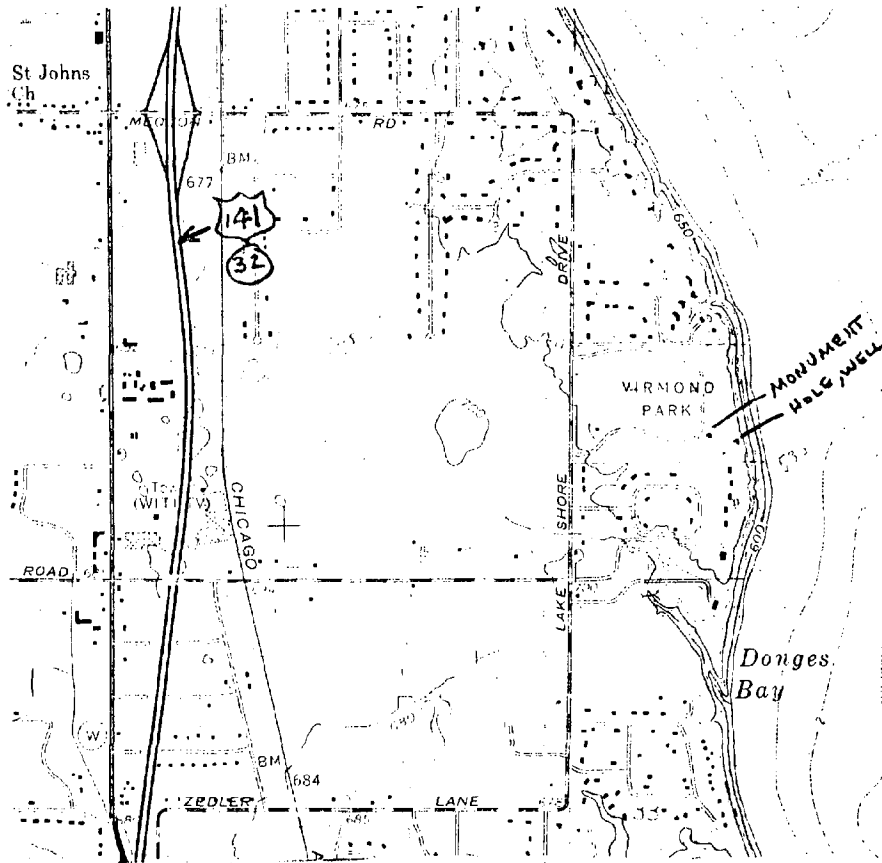
Geological and Natural History Survey
1815 University Avenue, Madison, Wisconsin 53703

LOCATION AND MONUMENTATION SKETCHES

Boring No. GT-6 Virmond PK, Ozaukee Co.; Thiensville Quad.
NE 1/4 SW 1/4 / sec. 28 / T. 9 N. / R. 22 E.

Date

Drawn by



Borehole: GT-6 Location: Virmond Park, Ozaukee County, T9N, Sec. 28

46

Depth	Flow Counts (split spoon)	Pocket Penetrometer	w_n	γ_d	w_L	I_P	% Clay	% Clay & Silt	ϕ	c	c_vane
5											
10											
15											
20			18.7	1.80	30.4	14.6			30.5	0.0	
25											
30											
35											
40			19.6	1.78	31.1	15.0	38.2	87.6	30.5	0.0	1.24
45											
50											
55			19.7	1.80	32.5	15.4		86.0	30.5	0.0	0.70
60											
65			sand above 70 feet					7.5	34.7	0.0	
70			16.7	1.90	22.5	7.3	29.8	79.7	30.5	0.0	
75											
80											
85											
90					27.0	12.5					
95											
100			silt seam inspected in split spoon samples								
105											
110											
115											
120								71.6			
125											
130											
135											

red-brown silty clay (fill)

grey sand

red-brown silty clay (fill)

silt

grey-brown silty clay (fill)

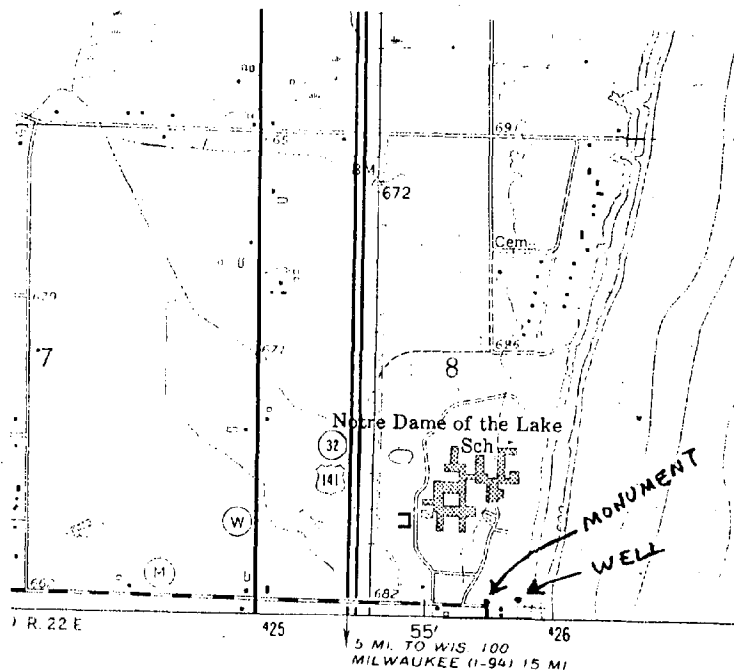
UNIVERSITY OF WISCONSIN--EXTENSION
 Geological and Natural History Survey
 1315 University Avenue, Madison, Wisconsin 53703

LOCATION AND MONUMENTATION SKETCHES

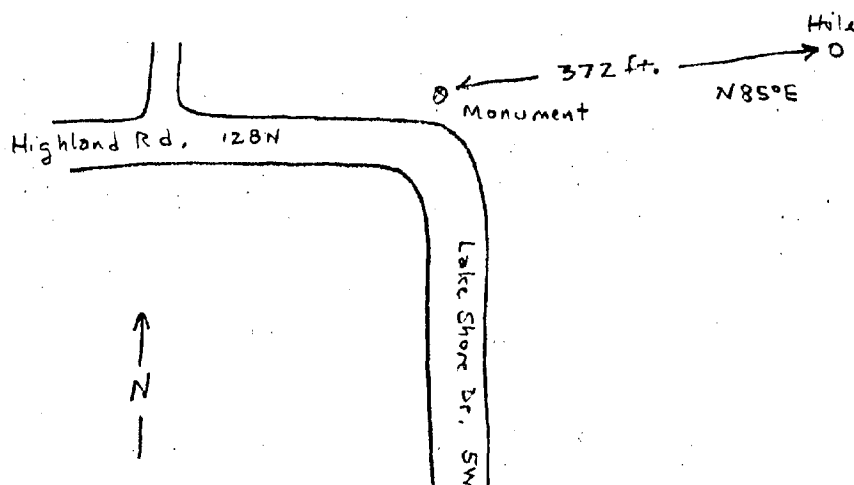
Boring No. GT-7, Cedarburg Quad. SW 1/4 / SW 1/4 / SE 1/4 / Sec. 8 / T. 9 N. / R. 22 E
 Ozaukee Co.

Date

Drawn by



Notre Dame of the Lake



LAKE MICHIGAN

Borehole: GT-7

Location: Notre Dame of the Lake Sch., Ozaukee Co., T9N, Sec. 8

Depth (feet)	Blow Counts (split spoon) (Std. Penetration)	Pocket Penetrometer	w _n %	Y _d (psf)	w _L %	I _p %	% Clay & Silt	φ°	c (psf)	c _{vane} (psf)	USCS class.
5											
10			16.6	114	33.2	16.5	37.6				
15							86.3				
20			17.9	114	30.0	14.4	85.9	31.3	0.0	3500	
25											
30			17.6	115	31.2	15.4	37.9				
35							85.8				
40											
45			17.2	114	32.5	13.7	38.8				
50			17.3	116	28.1	13.7	36.8	31.3	0.0		
55							85.8				
60			17.8	110	37.2	18.4	42.9				
65			8.8	(sand/gravel seam @ 65 ft.)			32.1				
70			15.2	119	28.3	12.7	33.2	31.3	0.0	3130	
75			16.3	120	27.3	9.6	30.0	34.8	0.0		
80			1.3	104			8.0				
85							42.3				
90			19.1	118	non-plastic		93.4				
95			19.2	117	15.4	3.0	7.0	33.7	0.0		
100			17.9	114			71.0	35.9	0.0		
105											
110											
115			18.8	112	25.4	12.1	29.6	29.6	82		
120					30.4	15.2	75.0				
125					32.8	15.2					
130											

dk. brown
silty
clay
fill

48

sand
fill

73

fine
sand
+
silt

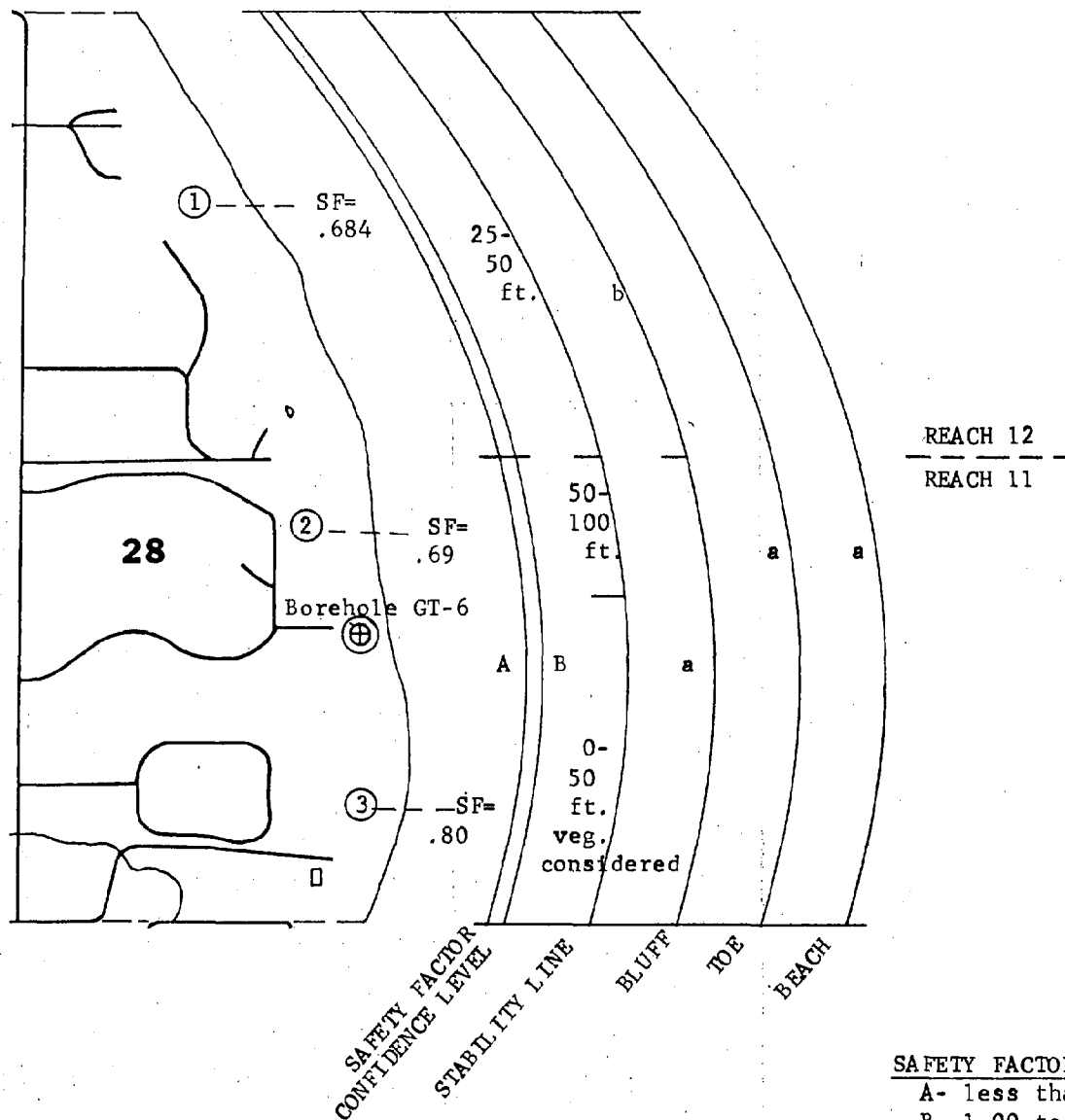
91

grey
silt

136

red-brown
lacustrine
clay

ML

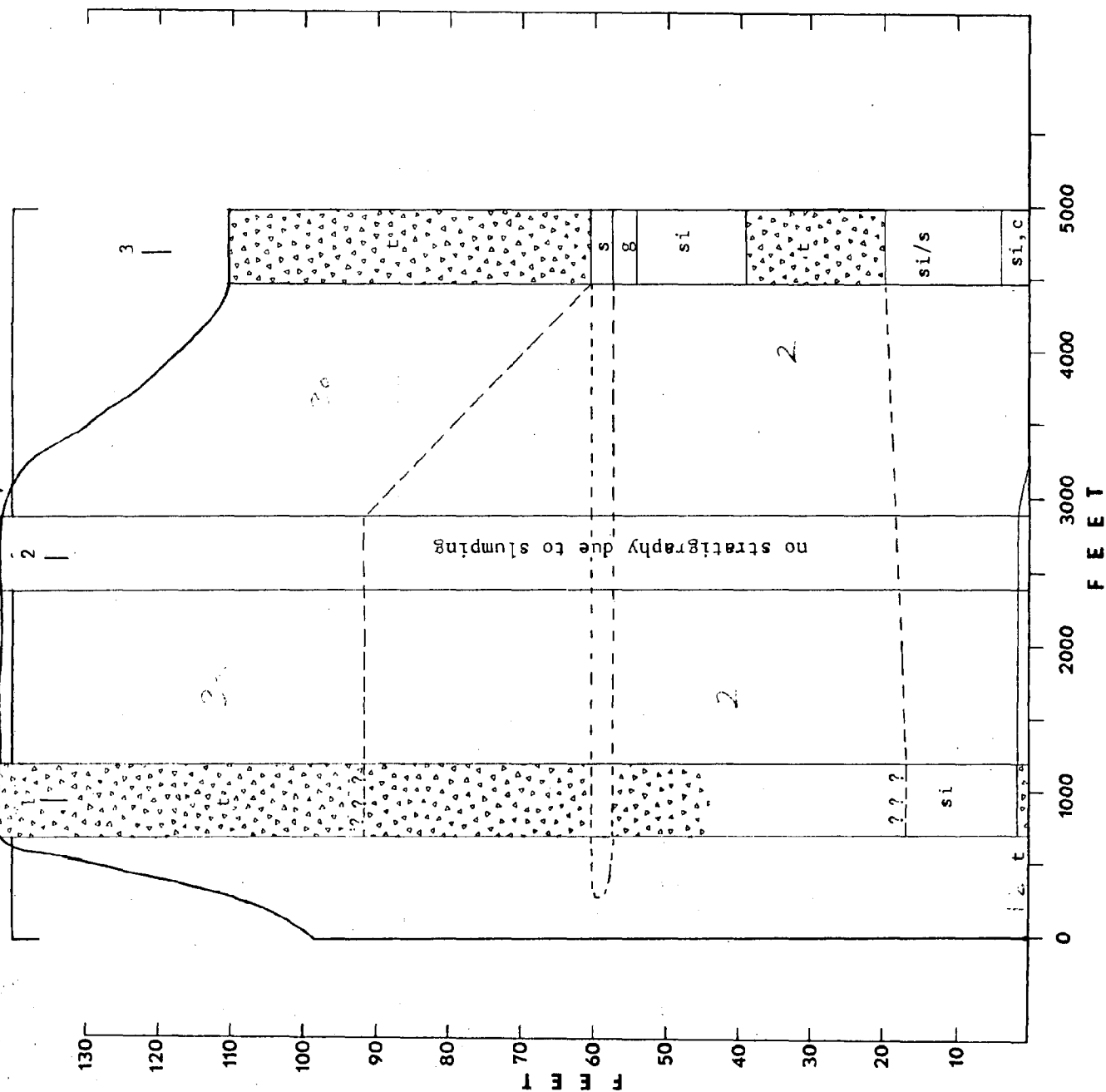
SAFETY FACTOR

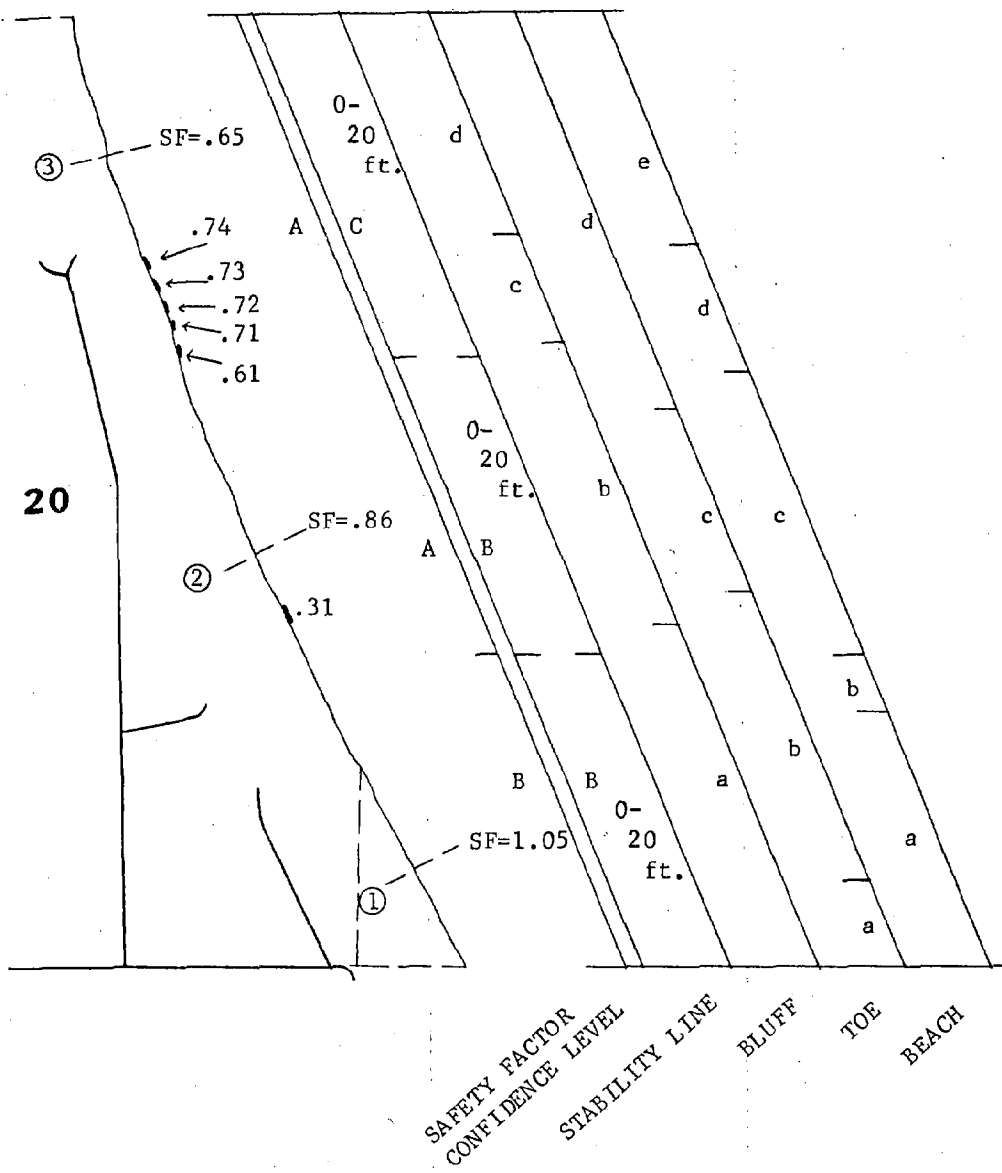
- A- less than 1.00
- B- 1.00 to 1.25
- C- greater than 1.25

CONFIDENCE LEVEL

- A- boreholes
(high confidence)
- B- near boreholes
stratigraphy visible
- C- no stratigraphy
visible (low confidence)

1. BLUFF	a-scarp face at the top of the bluff, translational movement (sliding, flowage and small slump blocks) all the way down the bluff face.	b-scarp face at the top of the bluff, small slumps continuously down the upper $\frac{1}{2}$ of the bluff along with translational movement. The lower $\frac{1}{2}$ consists of flowage, slump blocks and translational movement. The toe is being eroded by wave action.
2. TOE	a-slumped till covering in place silt and sand, in some places till.	
3. BEACH	a-15-25 ft.beach- pebbles and cobbles grading into medium grained sand at the toe of the bluff.	
4. STRUCTURES - none		



SAFETY FACTOR

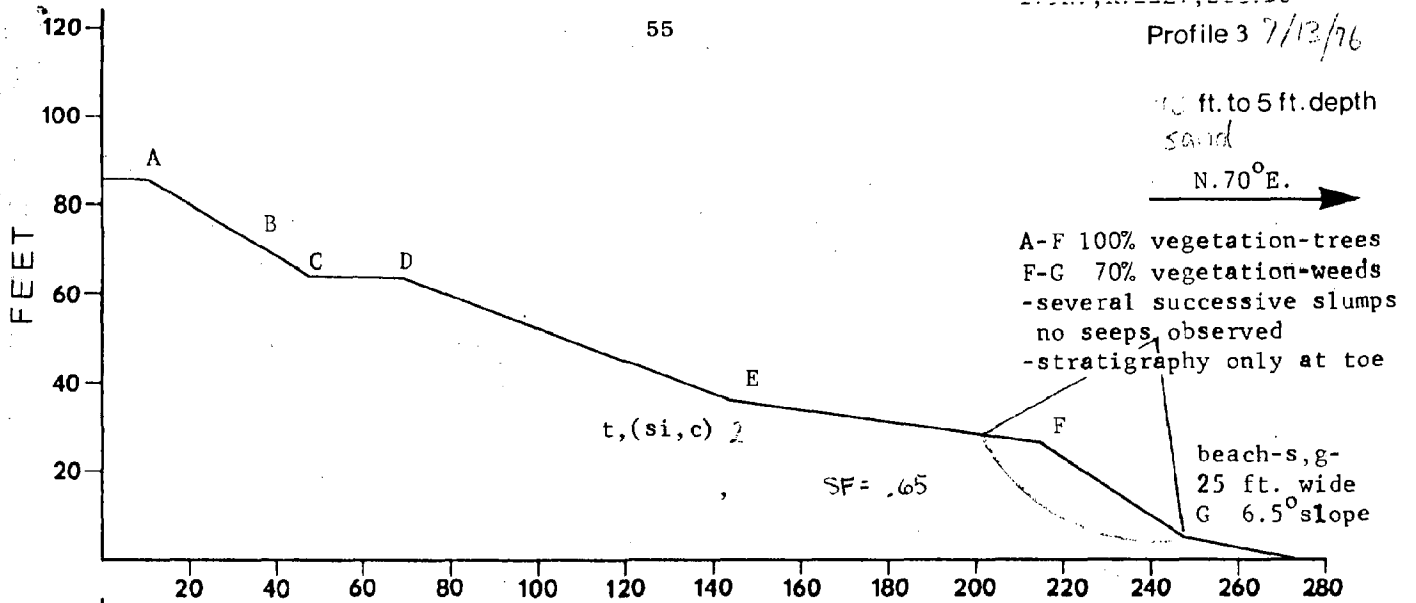
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

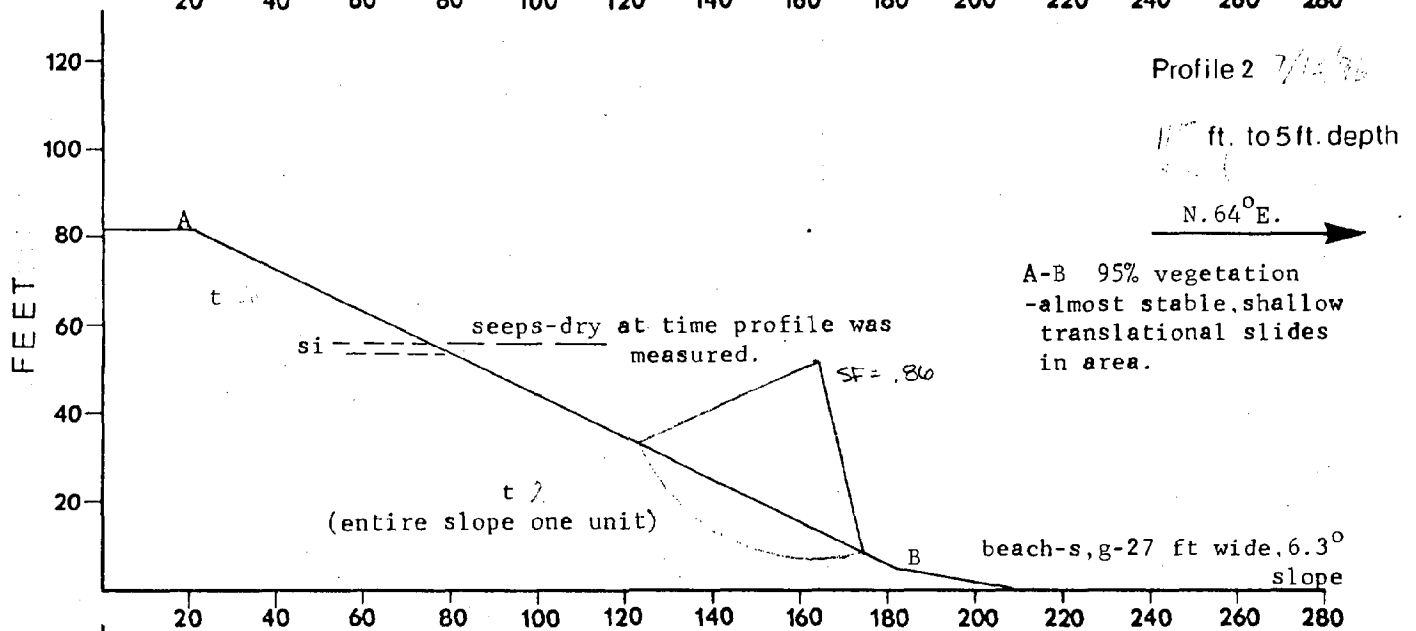
- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low confidence)

1. BLUFF	a-translational slides, toe erosion	b-translational slides on lower 3/4 of slope, rotation slump on upper 1/4 of slope	c-relatively stable, no recent failures	d-almost stable, several large slump blocks (slump blocks old, no recent slumping)
2. TOE	a-slide debris, red brown till and silt	b-in place silt, often with red brown till veneer 3 ft. above beach	c-in place gray clayey till	d-in place red brown till
3. BEACH	a- +20 ft. sand with gravel at high wave mark	b-5 to 20 ft. sand with gravel at high wave mark	c- +20 ft. sand with gravel at high wave mark	d- -5 ft. gravel
	e- +20 ft. sand with gravel at high wave mark			

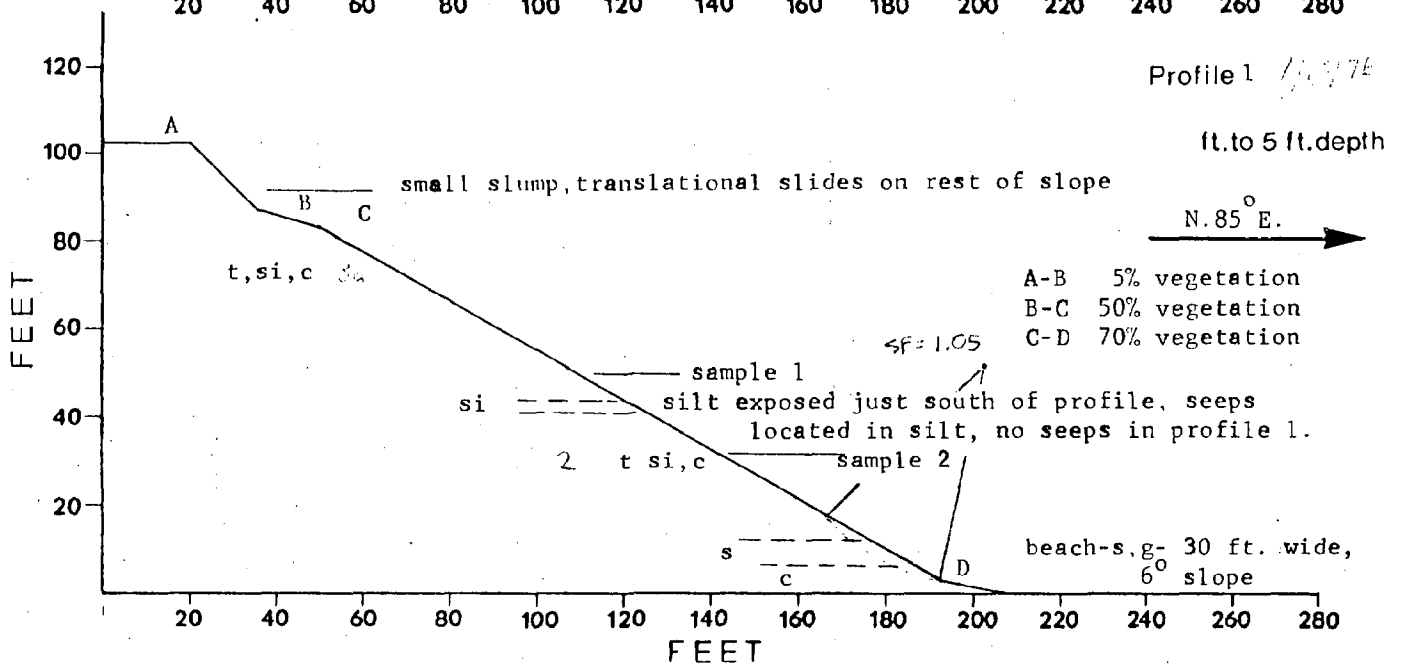
Profile 3 7/13/76



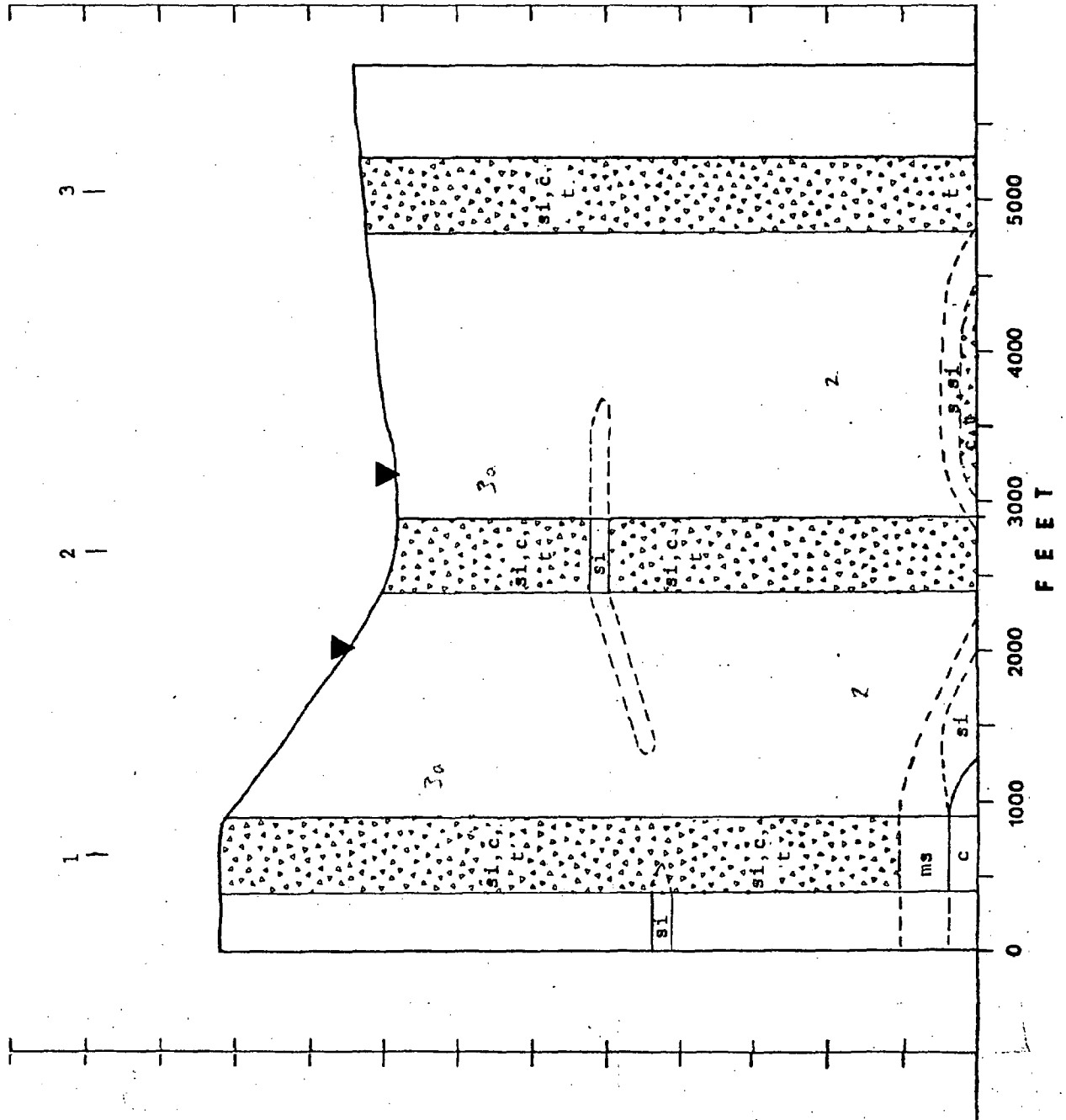
Profile 2 7/14/76

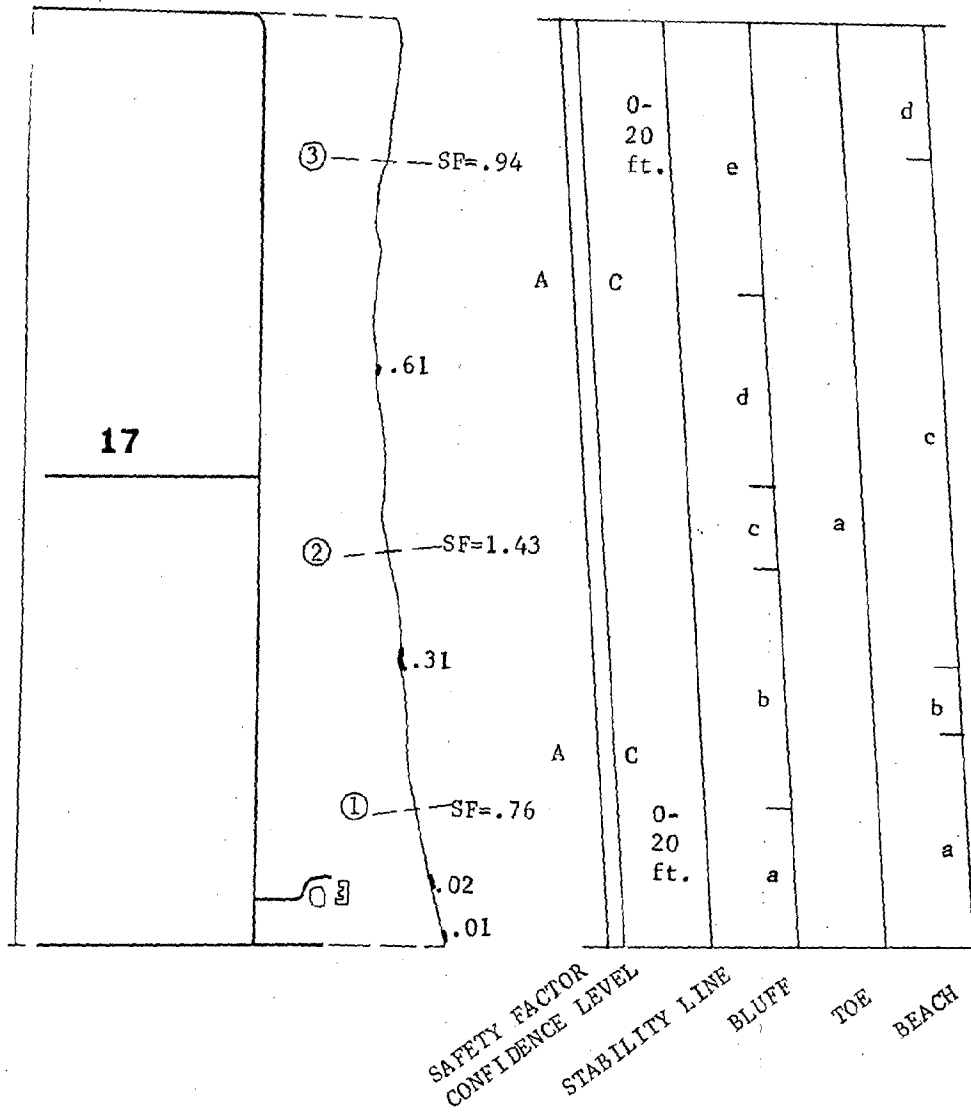


Profile 1 7/15/76



T.9 N., R.22 E., Sec. 20



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

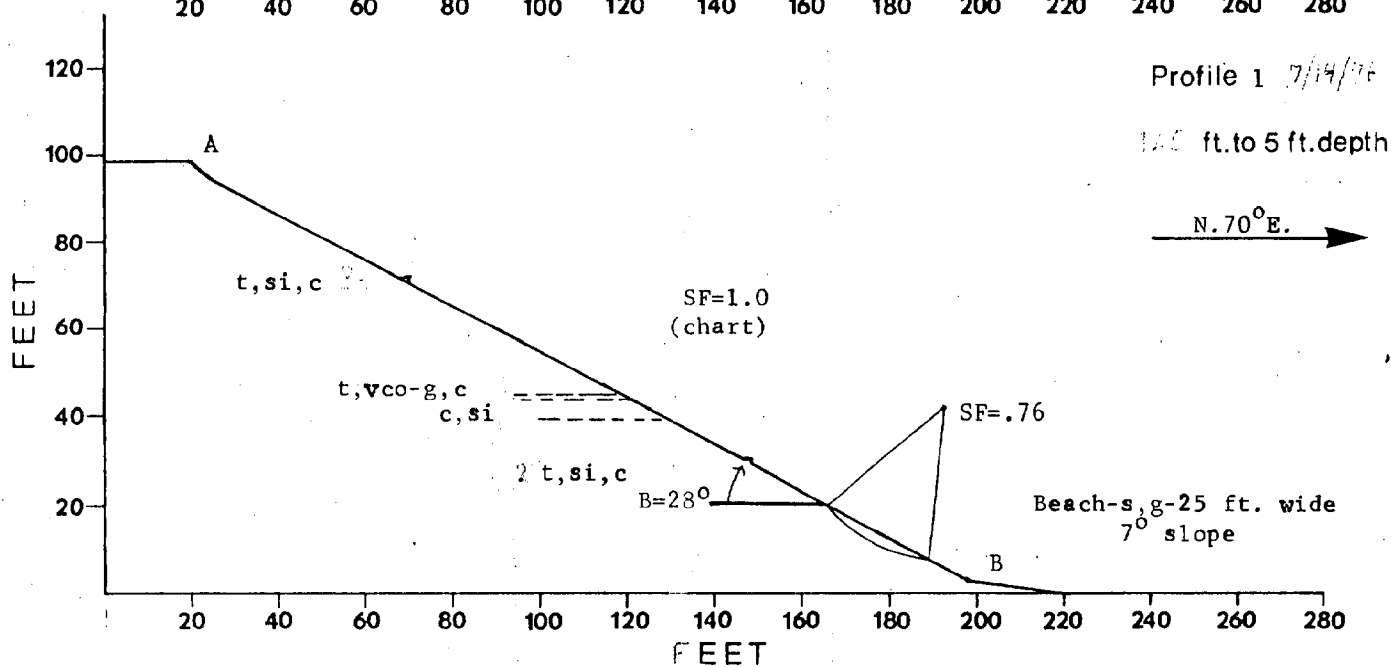
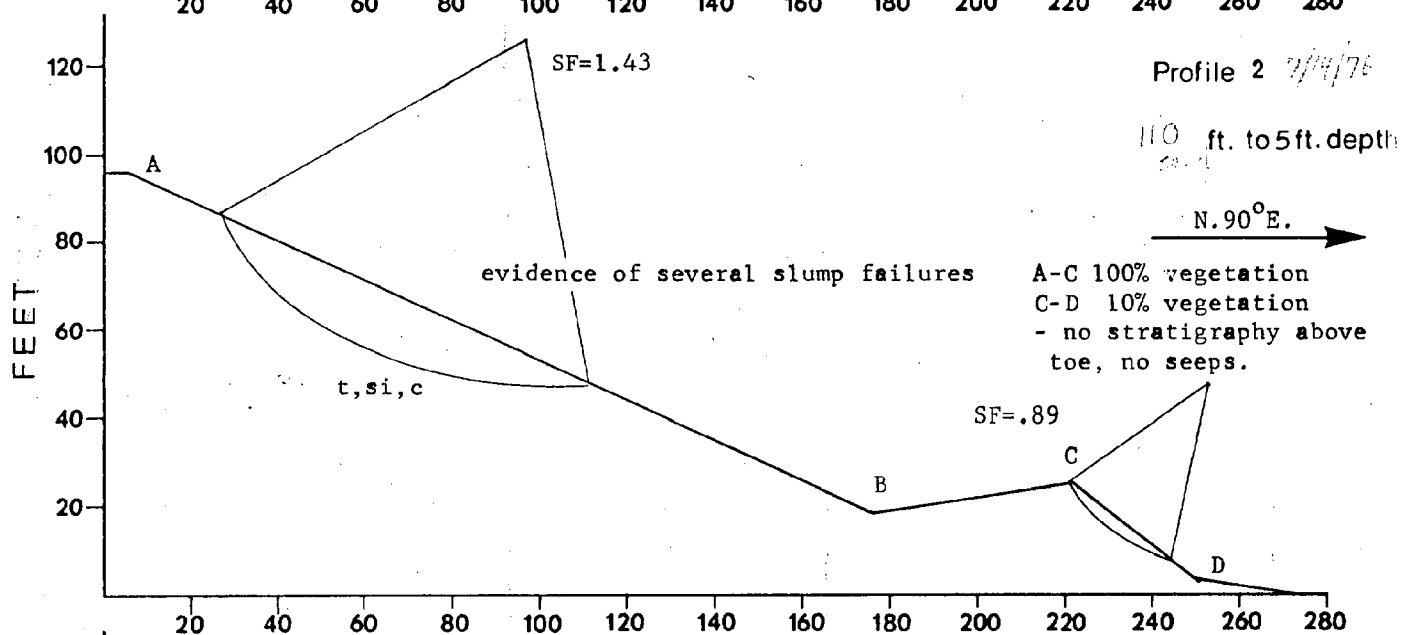
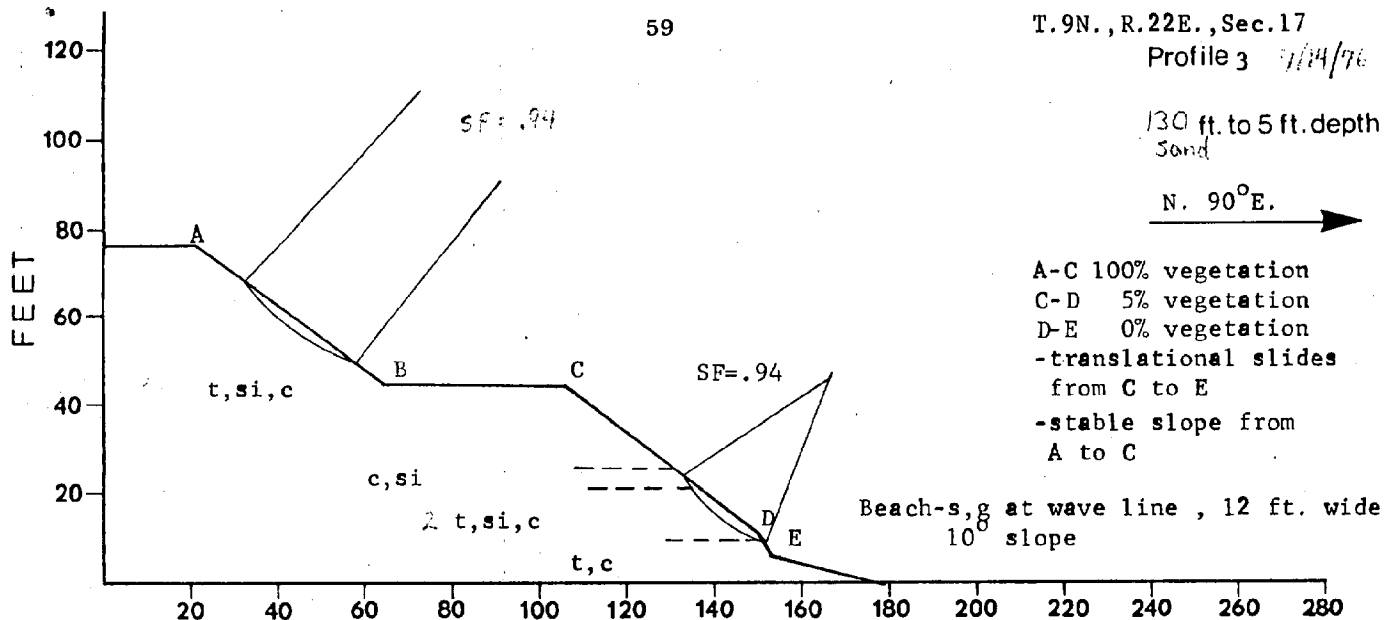
stratigraphy visible

C-no stratigraphy

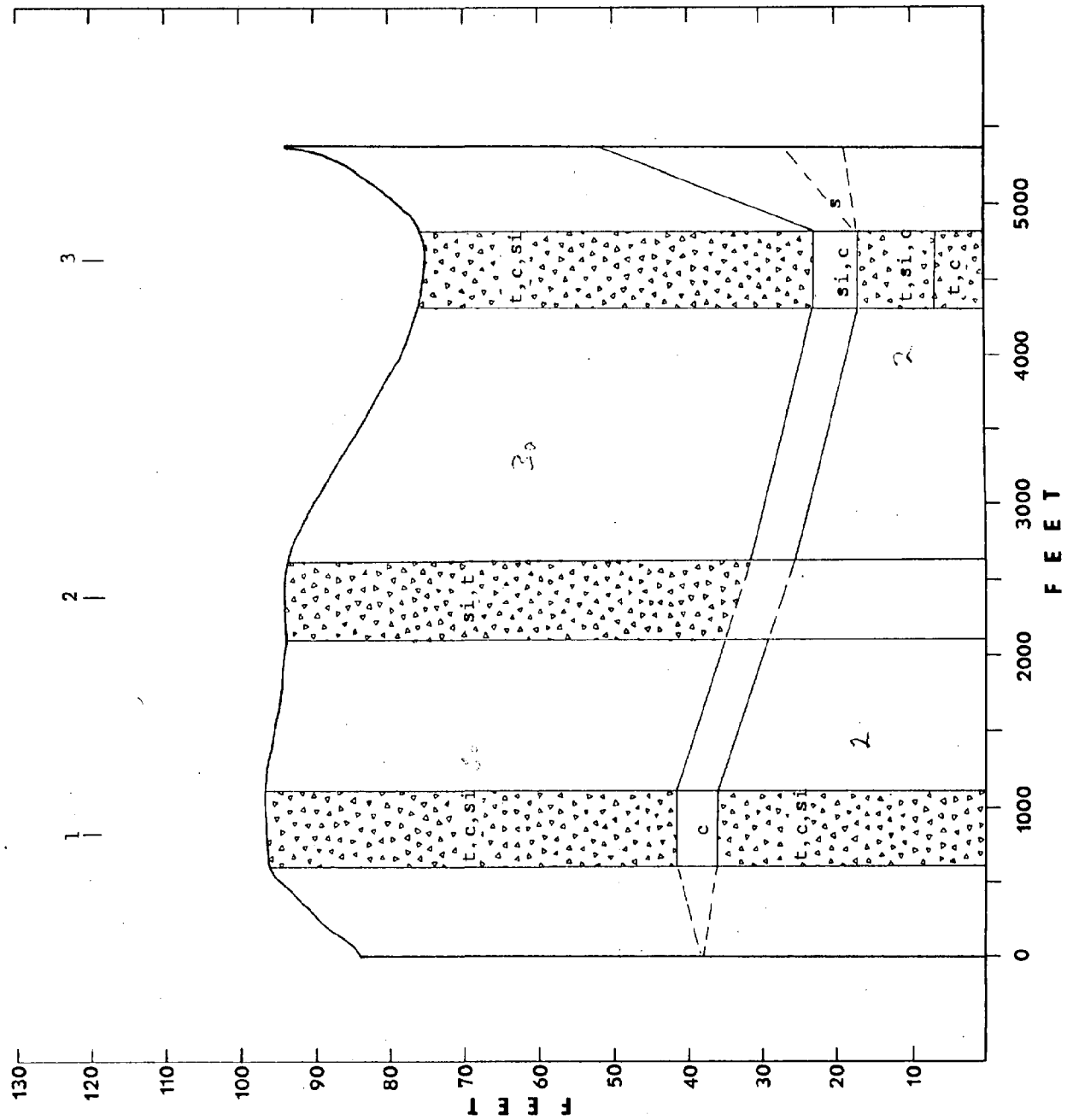
visible (low

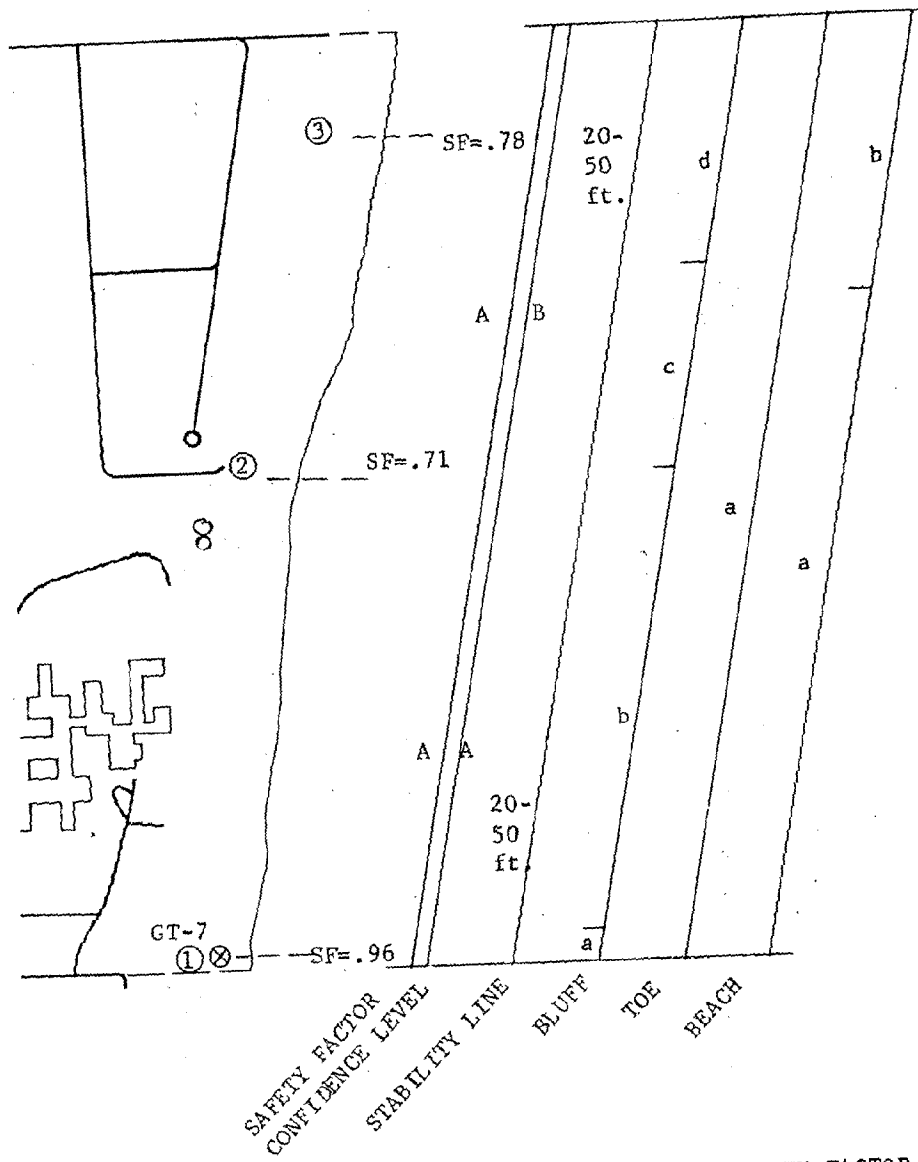
confidence)

1. BLUFF	<p>a-large deep seated slump failures, old slumps, no recent failures</p> <p>e-two large steps make up the slope, one old and very large slump block forms lower $\frac{1}{2}$ of bluff, translational slides on this block surface</p>	b-translational slides	c-large deep seated slumps	d-translational slides
2. TOE	a-toe material for the entire section is slumped and in place red-brown till			
3. BEACH	a- -20 ft. upper $\frac{1}{2}$ of beach is sand, lower $\frac{1}{2}$ is gravel	b-5-20 ft. upper $\frac{1}{2}$ is sand, lower $\frac{1}{2}$ is gravel	c- -20 ft. upper $\frac{1}{2}$ is sand, lower $\frac{1}{2}$ is gravel	d-5-20 ft. upper $\frac{1}{2}$ is sand, lower $\frac{1}{2}$ is gravel



T. 9 N., R. 22 E., Sec. 17



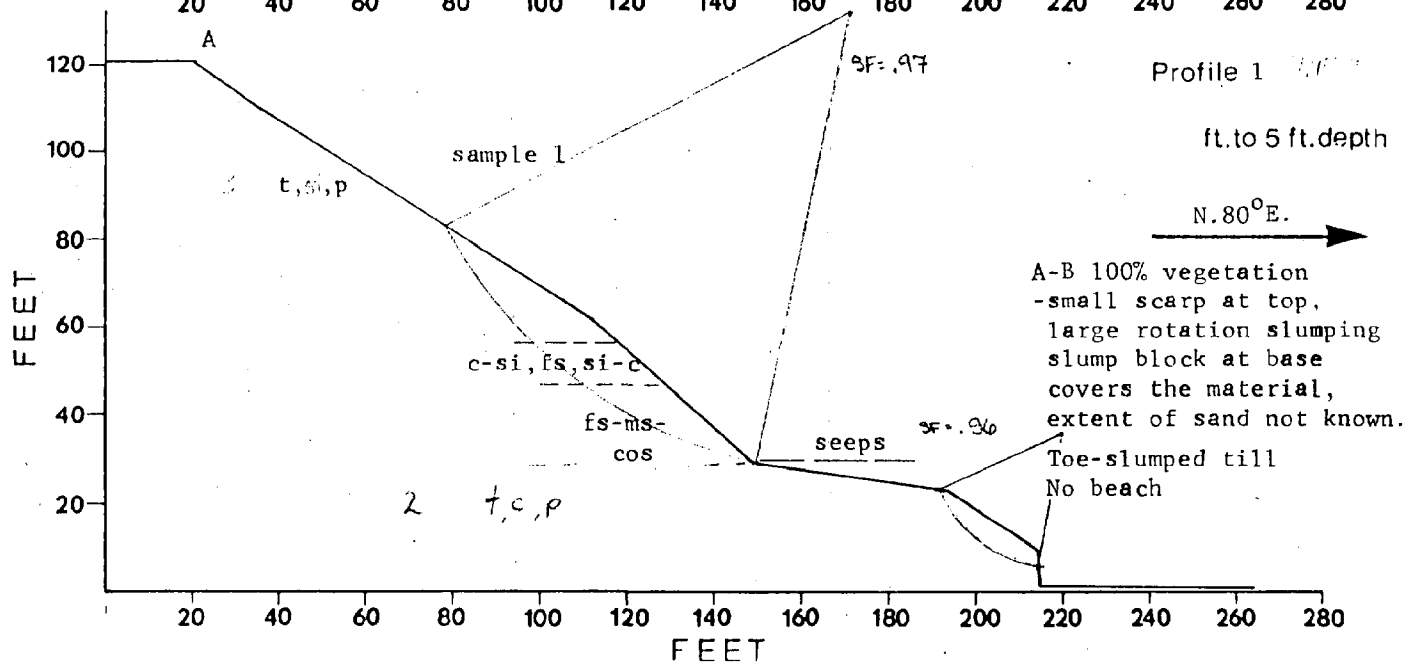
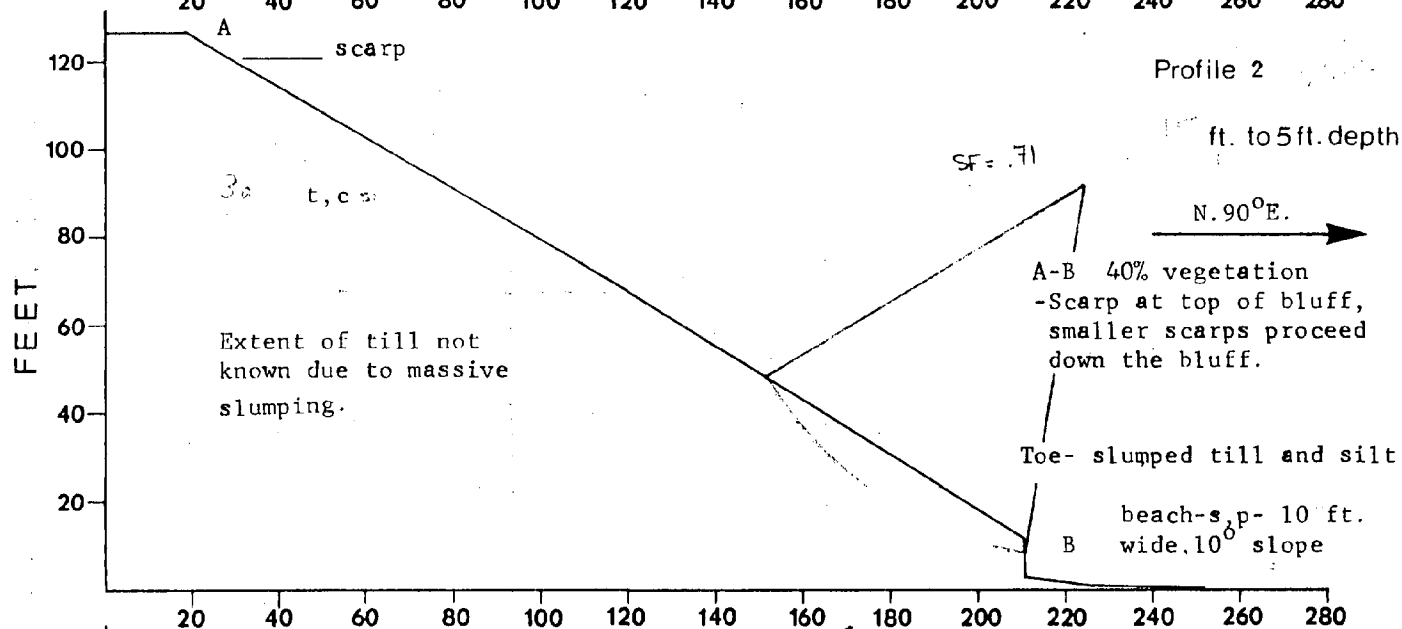
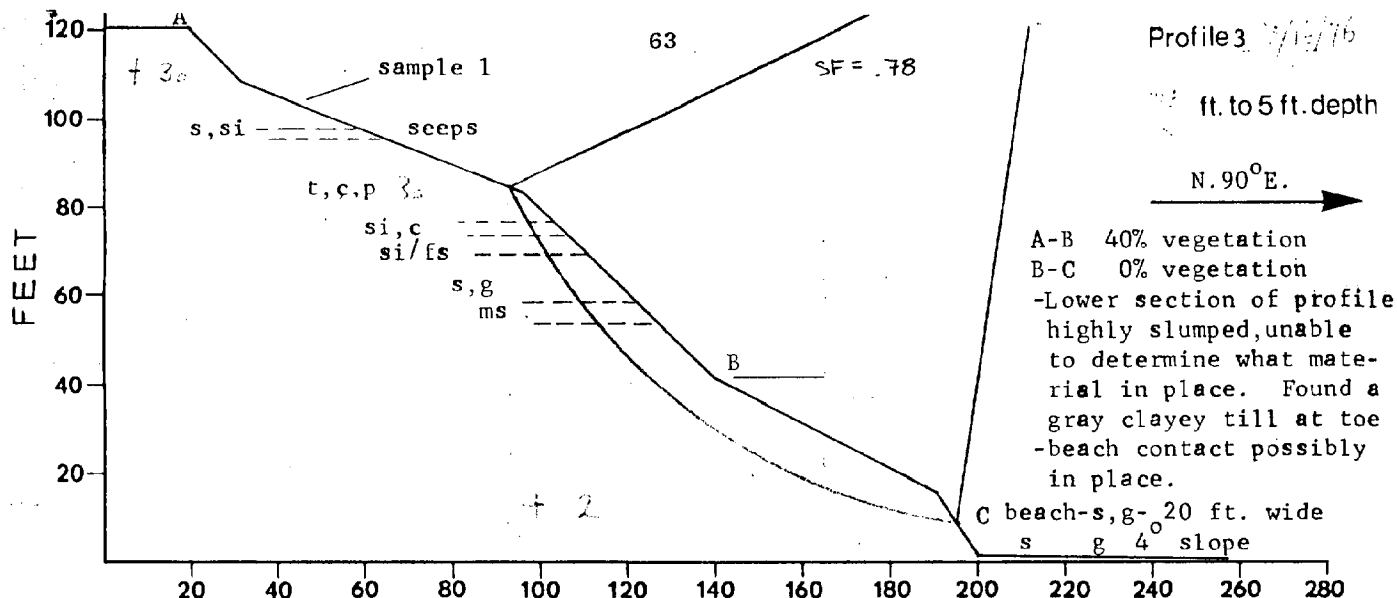
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

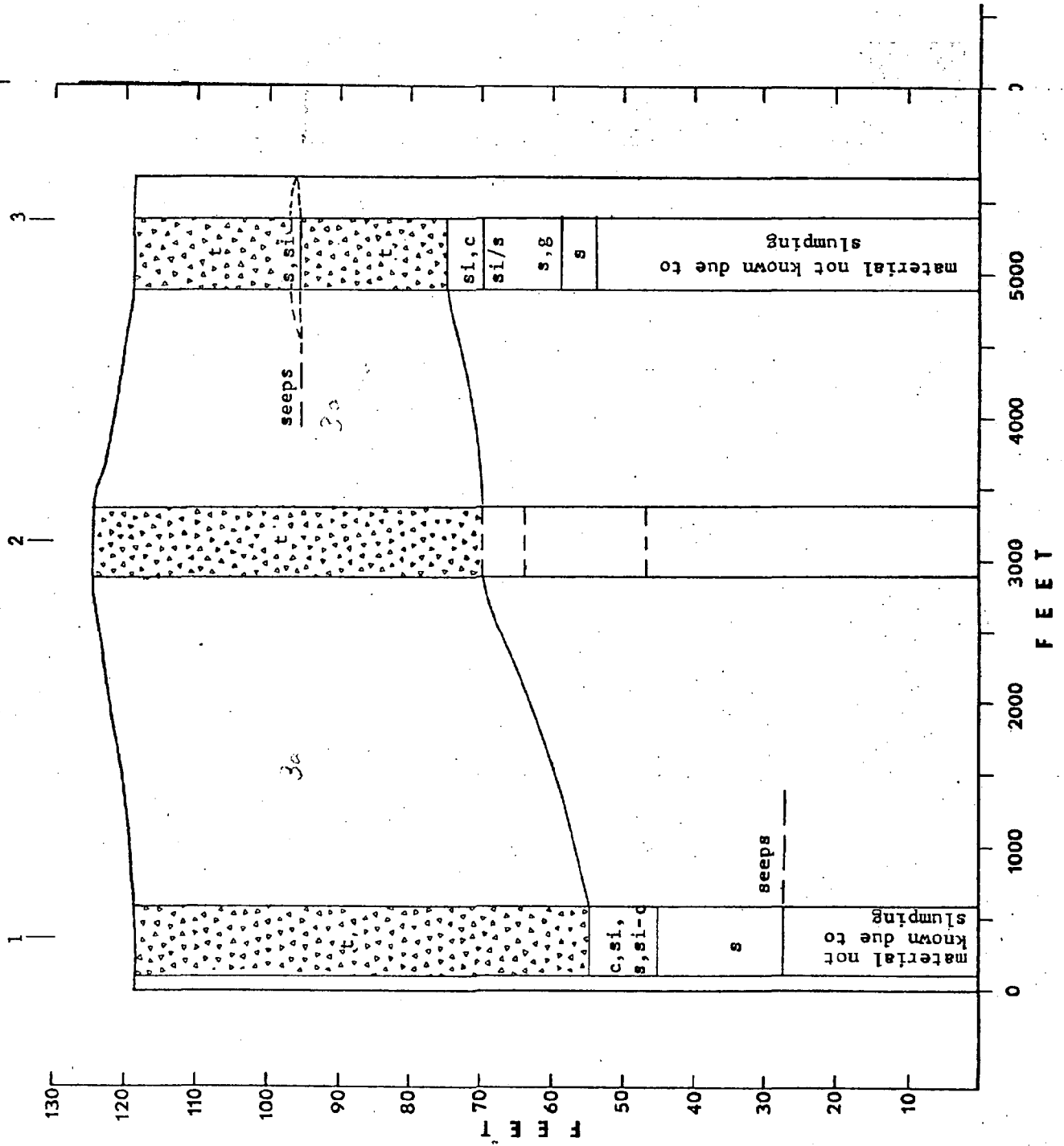
CONFIDENCE LEVEL

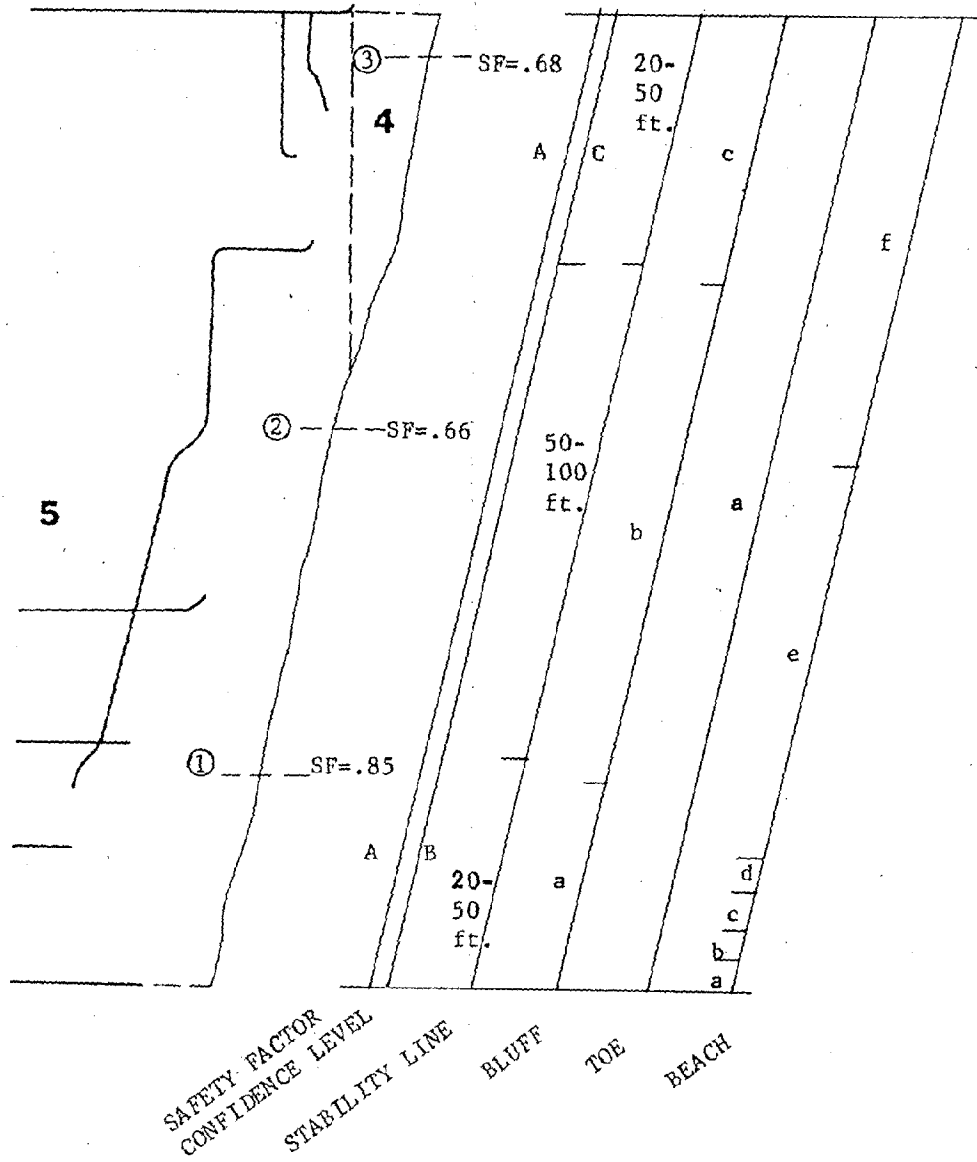
- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-large slump block forming an enormous scarp, 0% vegetation	b-unstable bluff, large translational sliding of blocks of material; movement aided by wave erosion of the toe; the largest sand layer seems to be the mechanism that sliding is occurring on; 0% vegetation on the toe face with 80% veg. most of the way up the face; a scarp is found continuously at the bluff top with 0% vegetation in many places; slope is approximately 30°.	c-unstable bluff, with translational sliding of material not blocks, down the face of slope; 10% to 50% vegetation, 30° slope, toe erosion aiding downward slope movement.	d-unstable bluff, rotational slumping of material, small fault blocks up the entire slope, 100% vegetation almost continuously up slope, except on the face of the slump block making up the toe; wave action on the toe producing unstable conditions, (downward movement)
2. TOE	a-slumped sand, silt, gravel and till; can be one or a combination of the above.			
3. BEACH	a-beach 0-10 ft. in width with pebbles and cobbles extending approximately $\frac{1}{2}$ the distance from the water's edge to the toe; medium grained sand extends to the toe.		b-beach 15-25 ft. in width, pebbles and cobbles extend $\frac{1}{2}$ the distance from water's edge to the toe, medium grained sand the remaining distance.	
4. STRUCTURES- none this section.				



T. 9 N., R. 22 E., Sec. 8



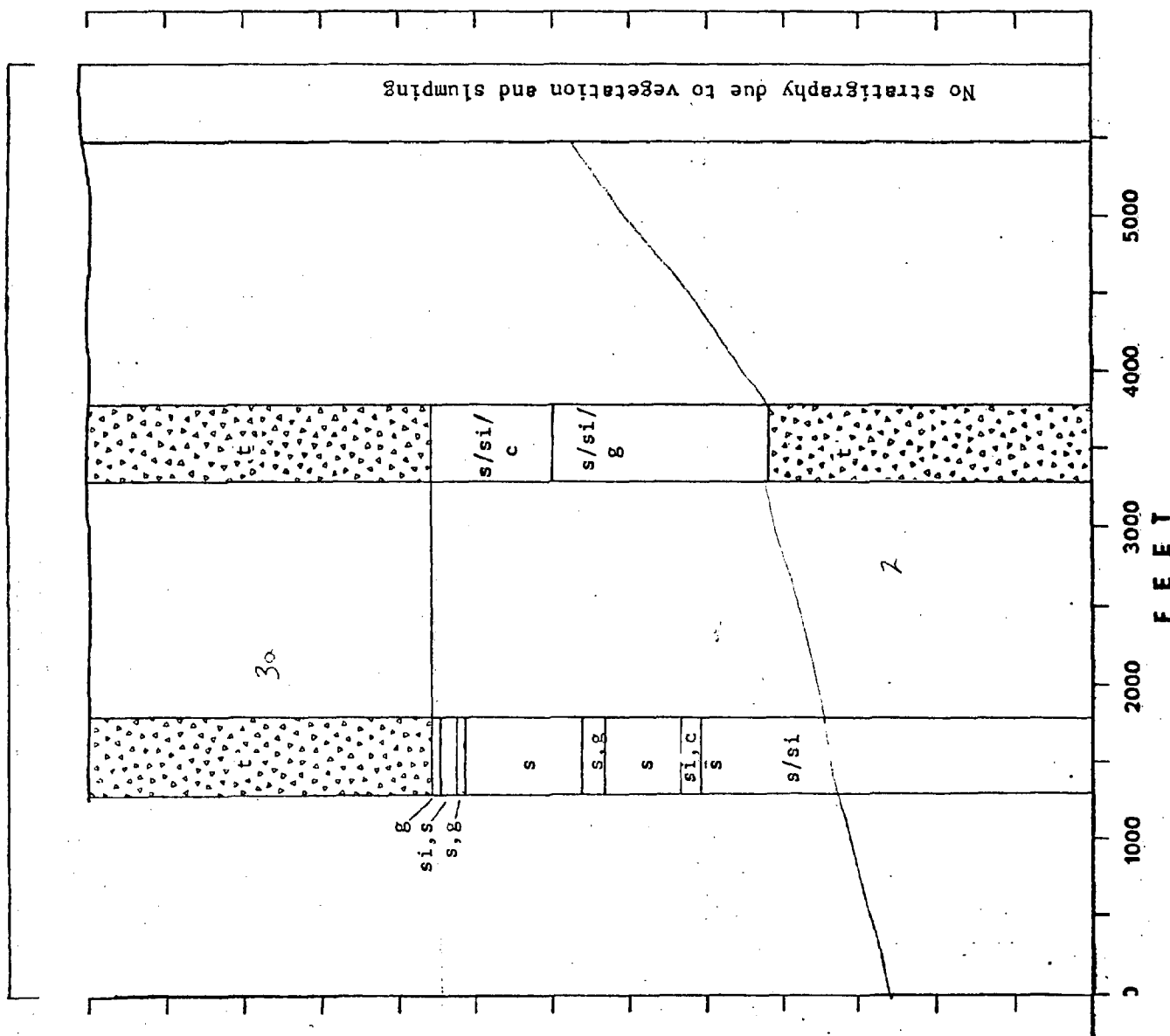
SAFETY FACTOR

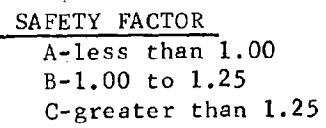
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-large drainage escarpment, 40% vegetation, large rotational slump block to the north of this, very unstable bluff, large scarp face at the bluff top, only vegetation is on top of slump block, average slope of bluff in this area is 40°.	b-one large drainage scarp on south border of this stretch, three additional large drainage scarps in this stretch, translational sliding of slump blocks down bluff, blocks noted at the toe (blocks make up toe material) vegetation located on top of displaced blocks, 36° average slope of bluff.	c-small rotational slumps all the way down slope, although 100% vegetation on the bluff, no seeps were noted, a large rotated slump block makes up the toe of the bluff, average slope of major bluff is 30°, scarp noted at top of bluff.	
2. TOE	a-toe material consists of slumped till, sand and gravel; each of these seems to be present independently or a combination there of, depending on the location along the section; this situation seems to be the result of translational sliding of till over a sand and gravel sequence, in places the till moves sand and gravel with it; none or very little vegetation is present on the toe face.			
3. BEACH	a-15-25 ft. in width, ½ gravel and pebbles at water's edge inward with ½ medium grained sand to toe of bluff	b-15-25 ft. in width, ½ gravel and pebbles from water's edge inward with ¾ medium grained sand.	c- -25 ft. beach, ½ gravel, ½ sand to toe	d-20 ft. beach, all gravel
	e-15-25 ft. beach, ½ gravel and pebbles from water's edge; ½ medium grained sand to toe	f-0-15 ft., ½ pebbles and cobbles, ½ medium grained sand		
4. STRUCTURES- none				



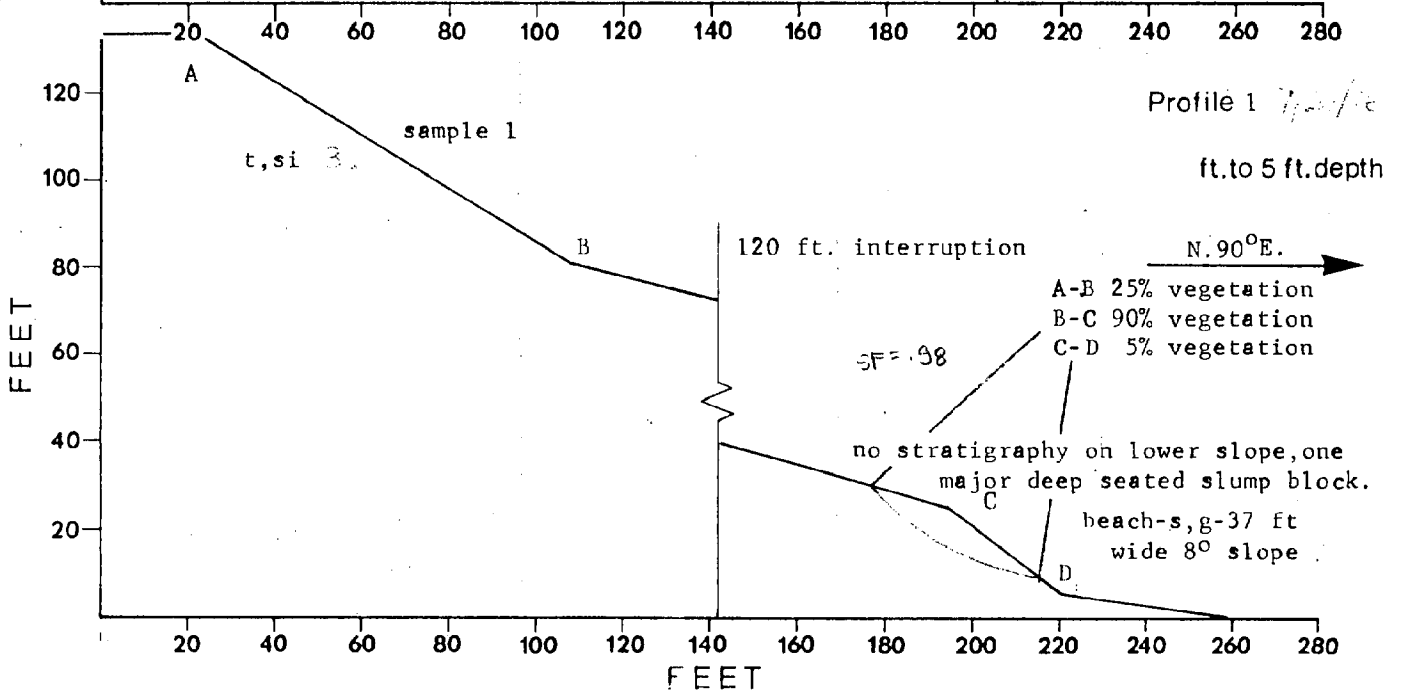
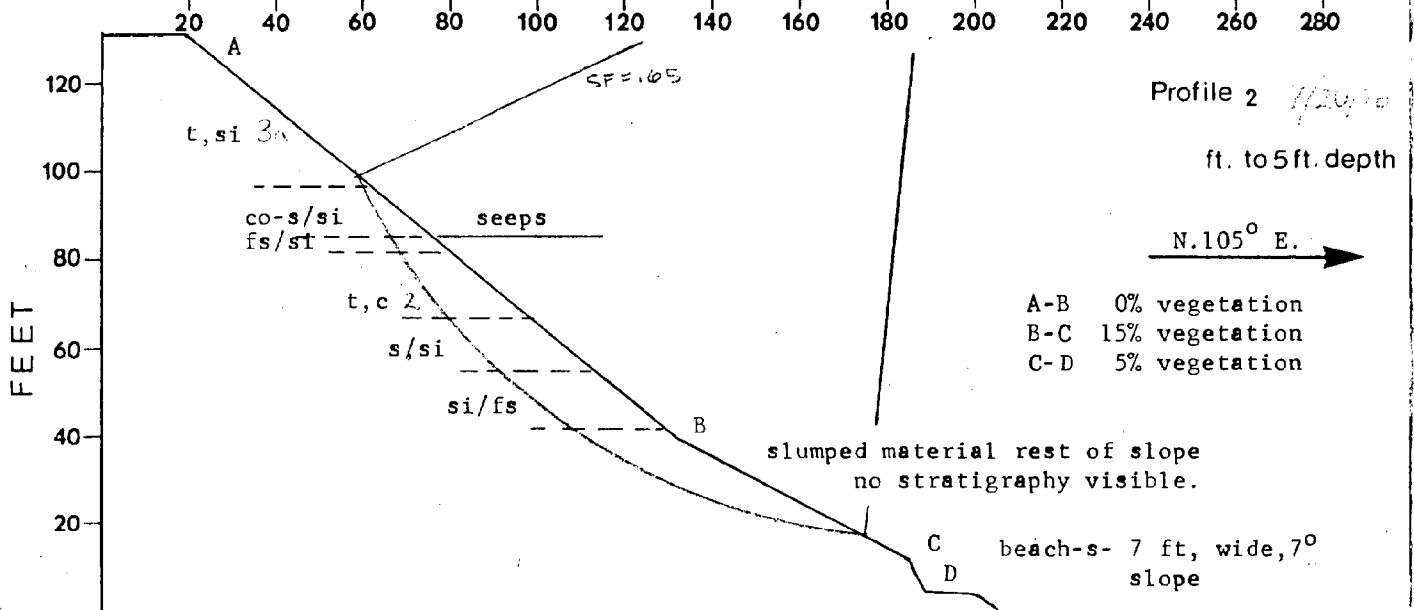
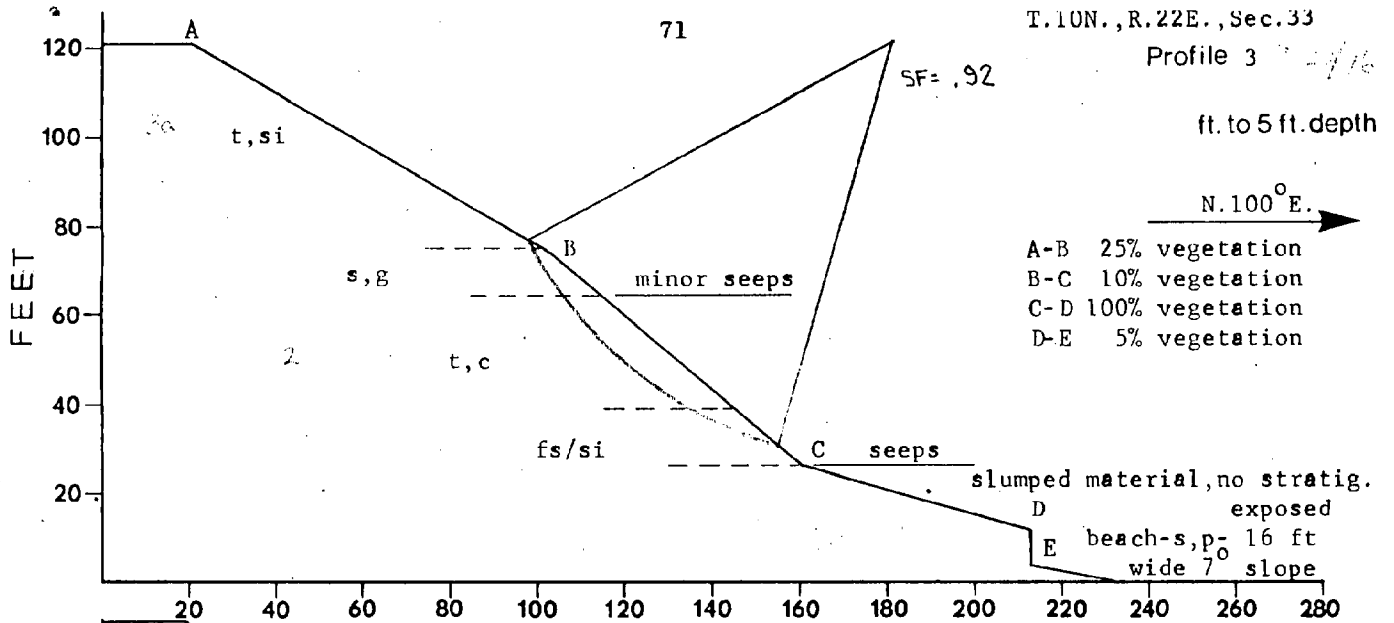


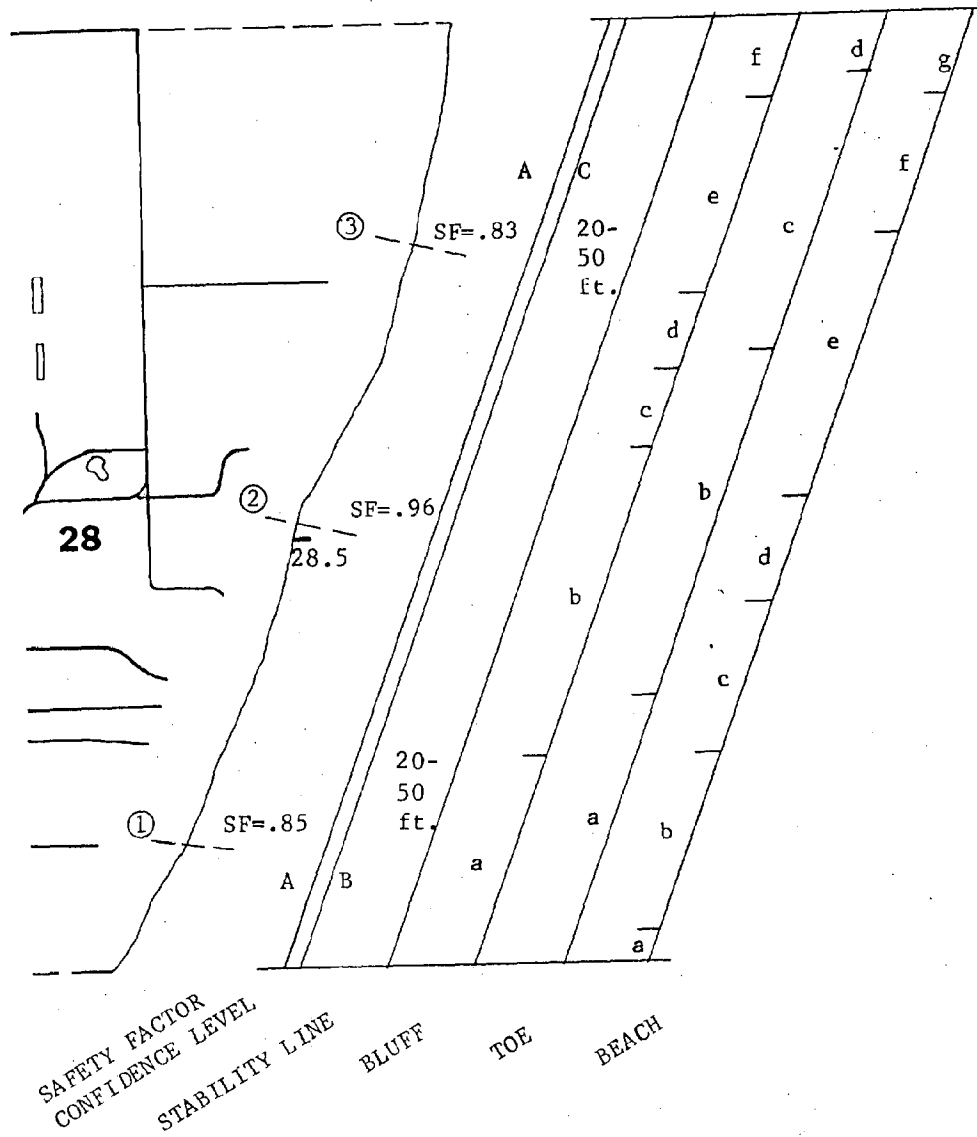
CONFIDENCE LEVEL
A-boreholes
(high confidence)
B-near boreholes
stratigraphy visible
C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-major deep seated slumping	b-shallow slumps and many slides.	c-major deep seated slumping	d-shallow slumping, many slides
2. TOE	a-slumped till	b-slumped till, silt and sand	c-slumped till	
3. BEACH	a- +20 ft. upper 2/3 sand, lower 2/3 pebbles and cobbles	b-5 to 20 ft. sand and gravel	c- +20 ft. sand on upper $\frac{1}{2}$, gravel on lower $\frac{1}{2}$	d-5 to 20 ft. sand and gravel
4. STRUCTURES- none in this section.				

T.10N., R.22E., Sec.33

Profile 3 7/16



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

C-no stratigraphy

visible (low

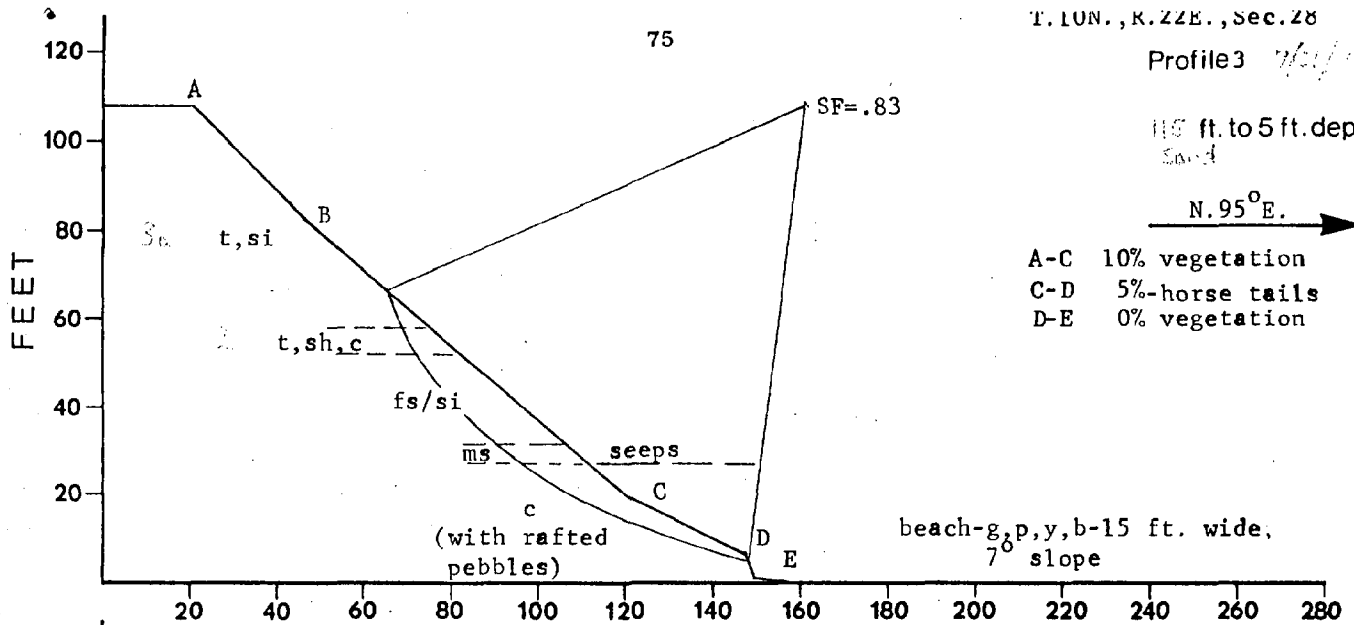
confidence)

1. BLUFF	a-translational slide, rapid toe erosion f-old slumping	b-major deep seated slump blocks (old)	c-tanslational slides	d-slumping (recent) shallow	e-translational slides
2. TOE	a-in place lacustrine silt and clay	b-slumped till and silt and sand	c-in place silt and clay (lacustrine)	d-slumped till and silt	
3. BEACH	a- -5 ft. gravel and broken trees	b- +20 ft. sand with gravel at water line	c-5 to 20 ft. upper 1/3 sand ,lower 2/3 gravel	d- + 20 ft. upper 1/2 sand,lower 1/2 gravel	e-5 to 20 ft. sand
	f- -5 ft. gravel	g-5 to 20 ft. sand			

Profile 3 *7/21/76*115 ft. to 5 ft. depth
sand

N. 95° E. →

- A-C 10% vegetation
C-D 5%-horse tails
D-E 0% vegetation

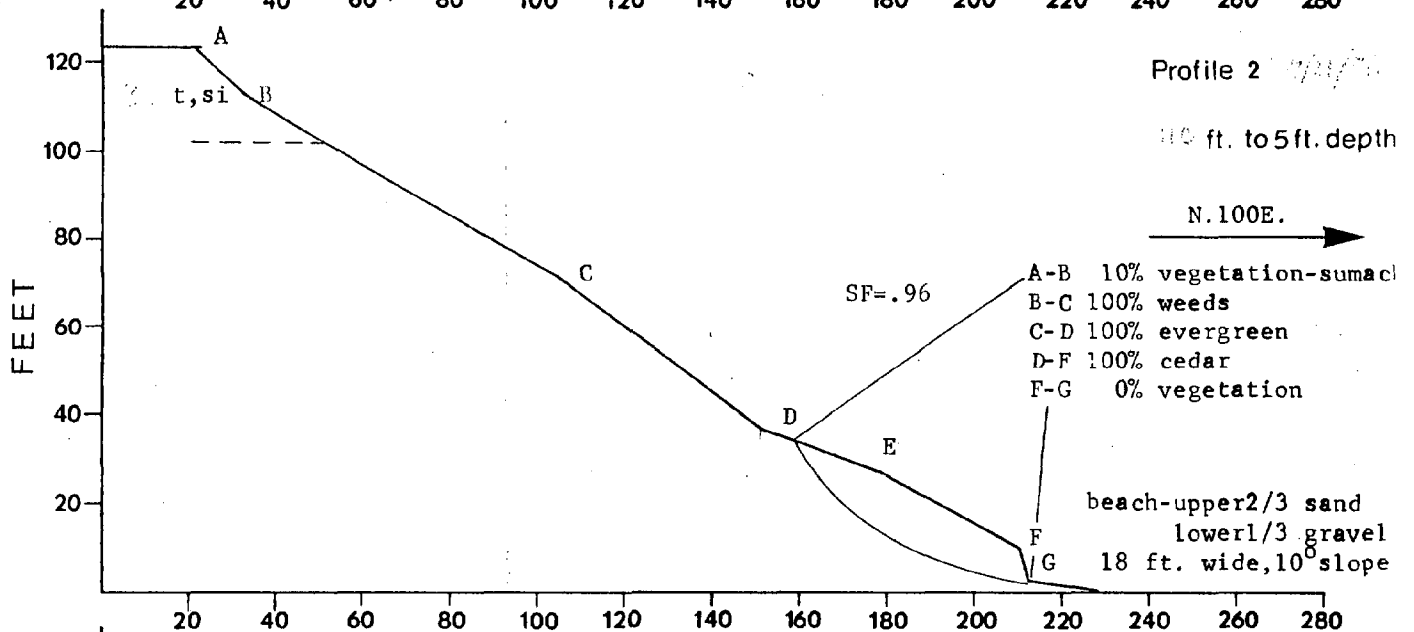
Profile 2 *7/21/76*

110 ft. to 5 ft. depth

N. 100° E. →

- A-B 10% vegetation-sumach
B-C 100% weeds
C-D 100% evergreen
D-F 100% cedar
F-G 0% vegetation

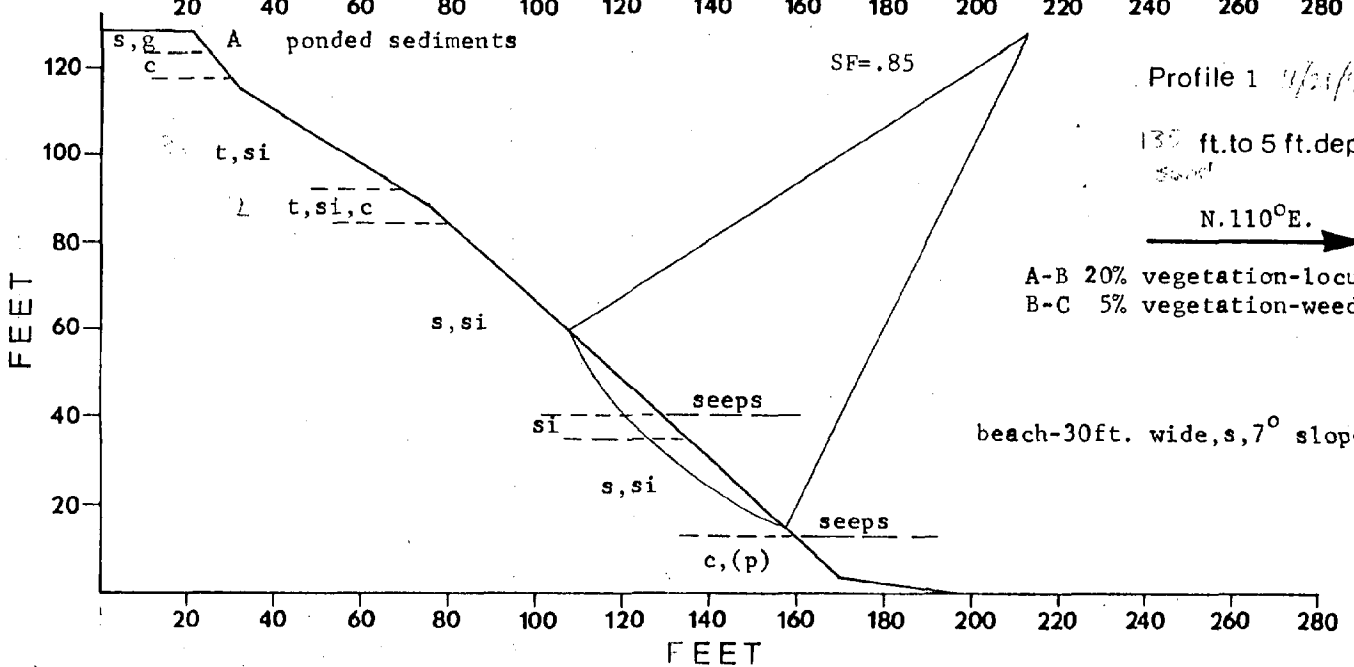
beach-upper 2/3 sand
lower 1/3 gravel
18 ft. wide, 10° slope

Profile 1 *7/21/76*130 ft. to 5 ft. depth
sand

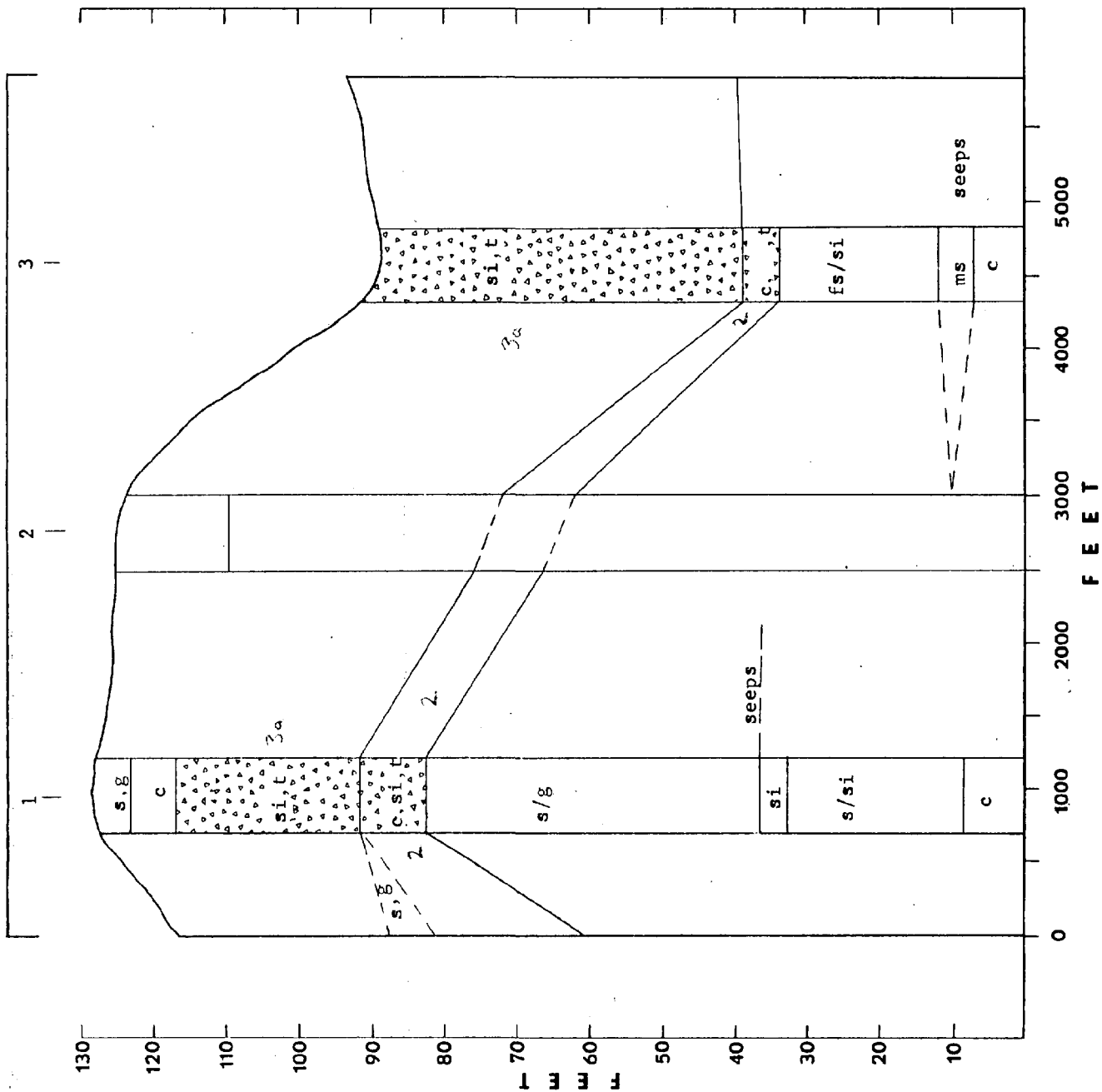
N. 110° E. →

- A-B 20% vegetation-locust
B-C 5% vegetation-weeds

beach-30ft. wide, s, 7° slope



T. 10 N., R. 22 E., Sec. 28



Field Report - Reach 13Location

This reach begins in Section 21, T.10N., R.22E., in Ozaukee County and extends through Section 33, T.11N., R.22E. in Ozaukee County. The length of the reach is approximately 5 miles. The land use in this reach consists almost entirely of farming with a very small percentage being residential. Where residential, the homes are located hundreds of feet away from the bluff top.

Reasons for Criticality

Reach 13 is ranked #7 having a value per mile of 18. This figure based on (1) the exceedingly fast short-term recession rate of up to 9 feet per year, (2) very high bluffs present, and (3) the Army Corps of Engineers 1952 Shore Damage Survey.

Reach 13A

Reach 13 is divided into two parts based upon the type of slope failure present. Part 13A is an area of high bluff with huge slump blocks resting at the foot of the slope.

Section 21, T.10N.

The first stretch of section 21 extends from 21.0 to 21.3. The first in-place stratigraphy in this stretch consists of 36' of gray silty till located about 38 feet above the lake. Over the gray silty till is 2 feet of sand and gravel and 26' of red-brown silty till. It is thought that the gray till is a locally reduced zone of the upper red-brown till. The stratigraphy of the lower bluff is obscured by slump debris. This stratigraphic column was obtained at the profile 1 location.

A large drainage ravine is located at 21.0. The ravine is 100% vegetated with large trees (8" diam.) and bushes. Adjacent to the ravine, to the north, is a section of bluff (approximately 220' in length) that has little vegetation

on it. A large scarp is found at the top of the bluff. Beneath the scarp, 3 successive small slump blocks are found down the bluff. The scarcity of vegetation probably means that bluff failure was fairly recent. The slope angle in this area is 35° .

Immediately to the north of this area, and encompassing the rest of this stretch is a partially vegetated section of bluff. The bluff seems to be semi-stable at this point with vegetation consisting of trees and bushes. At different points a slump scarp is located at the top of the bluff and a large rotational slump block is found at the base of the bluff. No vegetation is found on the face of this slump block but trees found on the surface of the block consist of pine and birch. Horsetails were found at the back of the block and a seep was also noted. The north end of this stretch is bounded by a large runoff escarpment with a large drainage ravine to the north of it. The sides of the ravine are not vegetated as is the case with the escarpment. The slope of the bluff in this section is 30° . Toe material in the southern end of the stretch consists of a blue-gray sandy, silty till covered by slumped and flow till from above. To the north, the toe material changes to silt and clay overlain by sand. (This is possible evidence of a change in stratigraphy).

The stratigraphy in the second stretch is similar to that given for the previous location. At profile 2 the lower gray silty till is 12' and overlain by 5' of sand and gravel and 32' of red-brown silty till. It is thought that the lower gray till is only a locally reduced part of the upper red-brown silty till. Again the stratigraphy of the lower bluff is observed.

A slump scarp is found at the top of the bluff continuously through this section. A large rotational slump block is found throughout this stretch except in two places (21.4 and 21.5). At these two points, drainage escarpments have formed, incising through the slump block at the toe. Vegetation in the

first escarpment (21.4) is 100%, and consists of trees and bushes. Vegetation on the second escarpment (21.5) is spotty. Where there is vegetation it is 100% and consists of trees and bushes. The bluff in this stretch is highly unstable with a 41° slope. The slump scarp at the top is incised in places, possibly the result of recent failures. A major seep is located at the top of the slump block, through this stretch. Standing water was found on the upper surface of the block.

The vegetative cover in this stretch is spotty. Where vegetation is found, it is 100% and consists of trees, horsetails, and juniper bushes. The face of the slump block has 0% vegetation. From 21.3 to 21.5 the toe material consists of interbedded sand, silt, and clay overlain by sand. The covering of vegetation is 100% on the upper surface of the block through the stretch.

The final stretch in section 21 extends from 21.7 to 16.0. Due to extreme vegetative cover, no stratigraphy was visible in this section except at the top of the bluff. This consists of red-brown clayey, pebbly till, the thickness of which is not known due to slumping and vegetation. It is possible that the remainder of the stratigraphy of the bluff in this location is similar to that of profile 2 (28.5), but the fact that there is such a marked change in bluff failure characteristics is probably evidence for some stratigraphy change.

A scarp is found at the top of the bluff, which extends the entire length of this stretch. 0% vegetation is found on the scarp. At the lower extent of the scarp, there is a marked change in slope (40° to 20°) and also a marked increase in vegetation (90%). The type of vegetation found in this area is horsetails. Further down the slope there is another marked change in slope (20° to 0°) and the vegetation changes from 90% to 100%. The vegetation here is trees, grass, juniper bushes and horsetails. Further down the bluff the slope changes to 15° and four successive slump blocks are found extending all the way to the beach. A 100% vegetative cover is found on these slump blocks

which includes trees, grass, juniper bushes and horsetails. The toe of the bluff has approximately 10% vegetation on it, and consists of gray silty till with slumped red-brown clayey pebbly till over it. This whole stretch forms one large rotational slump area, with successive failures continuing up the slope. Down slope movement of material is aided by wave action undercutting toe material. No seeps were found to be active, but evidence of their present (horsetails) was obvious.

Beach conditions change throughout the section. From 21.0 to 21.2 the width is from 10 to 20 feet and the material consists of cobbles and pebbles from the water's edge half the distance to the toe. Medium grained sand continues from this point to the toe. From 21.2 to 21.4 the width is from 10 feet to 20 feet but the material consists of medium grained sand with a few pebbles, cobbles, and gravel. From 21.4 to 21.5 the width is from 15 to 25 feet. Pebbles, cobbles, and gravel extend from the water's edge half the distance to the toe of the bluff. From this point to the toe, medium grained sand is found. From 21.5 to 16.0 the beach width varies between 10 to 20 feet and the material consists of intermixed pebbles, cobbles, and gravel.

Section 16, T10N

Best access to section 16 is by way of a dirt road (stemming from County C) which dead ends at the bluff on the northern section line. Access to the southern half of the section is through fields at the southern section line. Land use in Section 16 is both residential (only 5 homes) and farming.

Section 16 is a stretch of shore with two markedly different types of slope failure. The southern 2/3 of the section is an area of old but major, deeply seated slump blocks. The northern 1/3 is characterized by rapid recent sliding on a very steep barren bluff face.

The bluff in the slumping southern part of section 16 can be divided into 5 parts - each being a lobe or center of slump. These lobes are easily visible on the overhead air photos. A profile across the slump blocks resembles a terrace. There is a steep (almost vertical) wave cut toe, then a horizontal or slightly negatively dipping surface that is heavily vegetated with large trees. In most places the back edge of the slump block is very wet (swampy or boggy). A steep scarp (up to 50°) rises from the slump block to the bluff top. The slump blocks can be differentiated from a terrace by the (1) toe material present (which in this case is the upper red brown silty till with some sand and silt mixed in), (2) by the helter skelter tilt of the trees, (3) by the negative slope and ponded waters, (4) and by the steep barren scarp rising to the bluff top.

The most southern of the 5 lobes extends from 16.0 to 16.11. The toe of this slump block is being rapidly eroded by wave action because the beach, being less than 5 feet, offers no protection. Immediately north of this block at 16.15 is the mouth of a drainage channel. The beach at this point is greater than 20 feet and sandy. This material represents the bluff strata eroded from the drainage ravine by the stream. (The 20 foot pebble beach extends from 16.13 to 16.25.)

North at 16.25 the beach is again pebbly in texture and between 5' and 20' wide. This allows the erosion of the toe on the 2nd, 3rd, and 4th (numbered from the south) slump blocks.

Profile 1, measured at 16.57, shows the conditions present, with some modification at the north end of slumping zone. At profile 1 the beach is 28' wide, the greater width being attributed to a small stream entering the lake at 16.56. The topographic profile shows a 6 foot, near vertical, toe followed by a gently rising slope. This rise and the intermediate slope (between C and D on profile 1) has been deposited by the stream in an alluvial fan. The true scarp at the back of the slump block is represented by the slope B-C., which

is a very steep 50° . Vegetation on the different slopes is as expected; the steep toe EF, and scarp BC, are nonvegetated and the remaining lower angle slopes are between 60% and 90% vegetated. The only visible stratigraphy is directly above C, where 6 feet of sand and gravel is overlain by 11 feet of red-brown silty clay with sand lenses and pebbles, which is overlain by 21 feet of red-brown silty till. Seeps are located in the sand and gravel.

The northern most amphitheater scarp extends from 16.57 to 16.725. The beach along this stretch is from 5 to 20 feet wide and the toe is being eroded.

Reach 13B

The northern part of reach 13 is an area of rapid recession rates and translational sliding. The stretch of shoreline included in reach 13B extends from 16.73, T.10N., north to the protective structures surrounding Port Washington.

Section 16, T.10N.

The second type of failure mentioned previously is in evidence from 16.73 to the end of the section. This is a zone of rapid toe erosion triggering translational slides on the upper slopes of the bluff. Profile 2 is very characteristic of this stretch. The beach width at the profile 2 location (16.76) is greater than 20 feet as it is for the rest of the section. This width is not enough protection for the toe; consequently, there is rapid erosion and a near vertical face on the lower 16' of the bluff. The next 61 foot surface of the bluff has a 45° slope which decreases at the top to 30° . The total height at the bluff is 110 feet.

The stratigraphy exposed is as follows, from the base upward: 25 feet of gray pebbly cobbly silty till; 7 feet of brown-gray clayey sandy silt, with many pebbles; 2 feet of red pebbly clay; 4 feet of silty sand; 10 feet of interbedded fine sand, medium sand and gravels; 5 feet of red-brown silty clay with scattered pebbles; and finally 56 feet of red-brown silty till.

These conditions exist to the end of section 16 and with little variation continue 3 miles north to Port Washington.

Section 10, T.10N.

The central section of reach 14, section 10 is a uniform stretch of high bluff which is subject to translational sliding. Best access to the section is by way of a dirt road, branching from County C, and dead-ending on the bluff top at the southern section line. Alternate passage may be obtained through a private drive near the northern section line. Land use in section 18 is predominantly farming.

Profile at 10.1 is typical of the southern half of section 10. The beach, as it is throughout the section, is wider than 20 feet. The beach texture in the southern 3/4 of the section is sand along the upper half, and pebbles making up the lower half. In profile 1 the bluff is 108 feet high and has a constant 40° angle. This is very characteristic in that the height varies only a few feet in this section and that 40° is the average slope for the section. The only variance noticed was that in a few places the toe of the bluff is slightly steeper (up to 50°). The vegetative cover is 5%.

The stratigraphy, at profile 1, from the toe up is as follows: 20 feet of gray, pebbly, cobbly, silty till; 3 feet of red and green laminated lacustrine clay; 9 feet of interbedded fine sand and red clayey silt; 22 feet of interbedded sand and gravel; and finally extending to the bluff top is 41 feet of red-brown silty till.

These conditions continue without significant change to 10.5 where a large ravine interrupts the bluff. North of 10.6 to 10.85 the bluff is similar to that shown in profile 2.

In profile 2 (10.78) the bluff height has decreased to 104 feet and the slope angle has increased to 41° .

In profile 2 the stratigraphy has changed from that in profile 1. The gray pebble cobble till is exposed to a height at only 4 feet, making the fine-grained lacustrine sediments appear lower also. The fine-grained lacustrine sequence is as follows: 14 feet of gray sandy silts, silty clays and clayey silt, overlain by 6 feet of red silts with fine sand lenses, overlain by 12 feet of medium sand and gravel and 5 feet of interbedded silt and fine sand. On top of these units is a 22-foot thick wedge of very coarse sand and gravel. The uppermost unit is 41 feet of red-brown silty till. Seeps are located in both sand layers.

The beach width is 28 feet with the upper 1/3 consisting of sand and the lower 2/3 pebbles and cobbles. The beach slope is 7° .

At 10.82 a second ravine dissects the bluff for a short distance. Translational sliding remains the dominate form of slope failure to the end of the section, however there are some zones of slump in this northern two-tenths of section 10. Profile 3 was measured across one such failure.

Profile 3 at 10.92 is an example of a shallow rotational slump failure on the upper slope. The rotated block then slid down the remaining slope. The topographic profile shows the slumped debris as a large mound on the lower slope. This is the curve from B to E on the drawing. The stratigraphy was to a great degree obscured by the slumping material, however seeps in the debris removed enough material to identify the bottom of a 14-foot thick sand layer 22 feet above the water. Red-brown silt was identified above the sand layer. The uppermost sand and gravel of profile 2 was not located and it is thought that this layer has pinched out or at least is a very thin unit. It is possible that the slump was seated between the upper red-brown till and silt overlying the sand on a surface lubricated by water.

The beach below the slump is 30' wide and is composed mostly of pebbles and cobbles. The vegetative cover on the slope varied from 0% to 20% on the lowest parts to 50% and 80% on the upper slopes.

Of special note in this section is the presence of several large half cone shaped erosion structures on the bluff. These forms located at 10.17, 10.69, 10.71, and 10.99 are thought to be the shape produced by small field drainage channels present in the spring. All are heavily vegetated and show no evidence of large scale failure.

Section 3, T10N

The first stretch in this section extends from 3.0 to 3.8. The first in-place stratigraphy is located several feet above the toe due to slide debris of a flow veneer. Exposed above the foot is a medium sand; 7' of gray silty till; 3' of interbedded silt and sand; 3' of crossbedded sand; 9' of gravel and finally 52' of red brown silty till extending to the bluff top. This stratigraphy was obtained at the location of profile 1. (3.1).

Characteristic in this stretch of section 3 is an almost continuous scarp face at the top of the bluff. The only places this scarp face is not found is at the locations of the two runoff escarpments (3.2 and 3.7) and a drainage ravine (3.5). At these locations the vegetative cover takes a dramatic increase. Cover on the two runoff escarpments varies between 80 and 100% and consists of weeds and grass. Vegetative cover on the drainage ravine is 100% and consists of fairly large trees and bushes. The ravine extends approximately 900 feet back from the top of the bluff. Vegetative cover remains 100% throughout this distance. The ravine then extends north some 700 feet at which point it ends. Vegetative cover on the remaining bluff face in this stretch varies between 0 and 10%, consisting mainly of weeds with an occasional small tree.

Bluff failure in this stretch seems to be translational movement of the upper section of the bluff over the lower section. Groundwater sapping and possible chemical solution of the permeable materials aids the failure of the upper materials. At certain points in this section two separate seeps are evident (3.0 to 3.5), one approximately half the way down the bluff, and the other

approximately 3/4 of the way down the bluff. Flow of the upper till down the face of the bluff is also evident. Severe undercutting of the toe by wave action is seen, which in places exposes a sand layer at the bottom of the bluff which provides an easily undermined layer.

The second stretch in this section extends from 3.8 to 33.0. The stratigraphy in this stretch consists of 52 feet of red brown clayey, pebbly till underlain by 30 feet of a massive red silt with sand lenses underlain by 6 feet of fine to medium cross-bedded, interbedded sand underlain by 16 feet of interbedded red clayey silt and silty clay underlain by a blue-gray silty, sandy, boulder till the thickness of which is not known.

This stretch contains one drainage ravine (3.8) which extends approximately 200 feet back from the bluff top. The vegetative cover in the ravine is 100% and consists primarily of large trees and bushes. A scarp face extends from the ravine north to the end of the stretch and section. Vegetation is 0% on the rest of the bluff face.

Failure in this stretch is primarily translational movement of material down the bluff, leaving a veneer of red-brown till over the material stratigraphically beneath it. Failure could be aided by the fact that there is a seepage zone located at the bottom of the interbedded red clayey silt and silty clay bed. The ground water is sapping material from the bed, producing failure above it. Also, there is severe wave erosion and undercutting of the toe material, which consists of the blue-gray till. This too, aids in failure and down slope movement of the material above. The slope angle in this stretch is an unstable 40° .

The beach conditions in this section are uniform from the standpoint of material. The width varies between 10' and 25' with pebbles, cobbles, and gravel at the waters edge. At varying distances inward, depending on the width of the beach at that point, the gravel, pebbles, and cobbles grade into a medium grained sand which extends to the toe of the bluff.

Section 3, T.11N.

The first stretch in section 33 extends from 33.0 north to 33.5. The stratigraphy in this stretch consists of 10' of blue-gray, silty sand; cobble till at the base and overlain by 23' of red and green mottled clay and clay silt; 26' of fine and medium grained crossbedded sand and finally extending to the bluff top 76' of red brown silty pebbly till. This stratigraphy is obtained at the profile 1 (33.0) location.

The drainage escarpments found in this stretch are not excessively large and are found throughout its distance. The major portion of the vegetation in the stretch is found in these escarpments. The vegetative cover ranges from 90% to approximately 30%, with an average of 50% in the drainage channels. Vegetation is comprised mainly of weeds. (Trees are found back from the bluff, but not on the face itself.) Between the drainage channel the vegetative cover is composed of weeds. Average vegetation cover is 10%. The vegetation does nothing for slope stabilization.

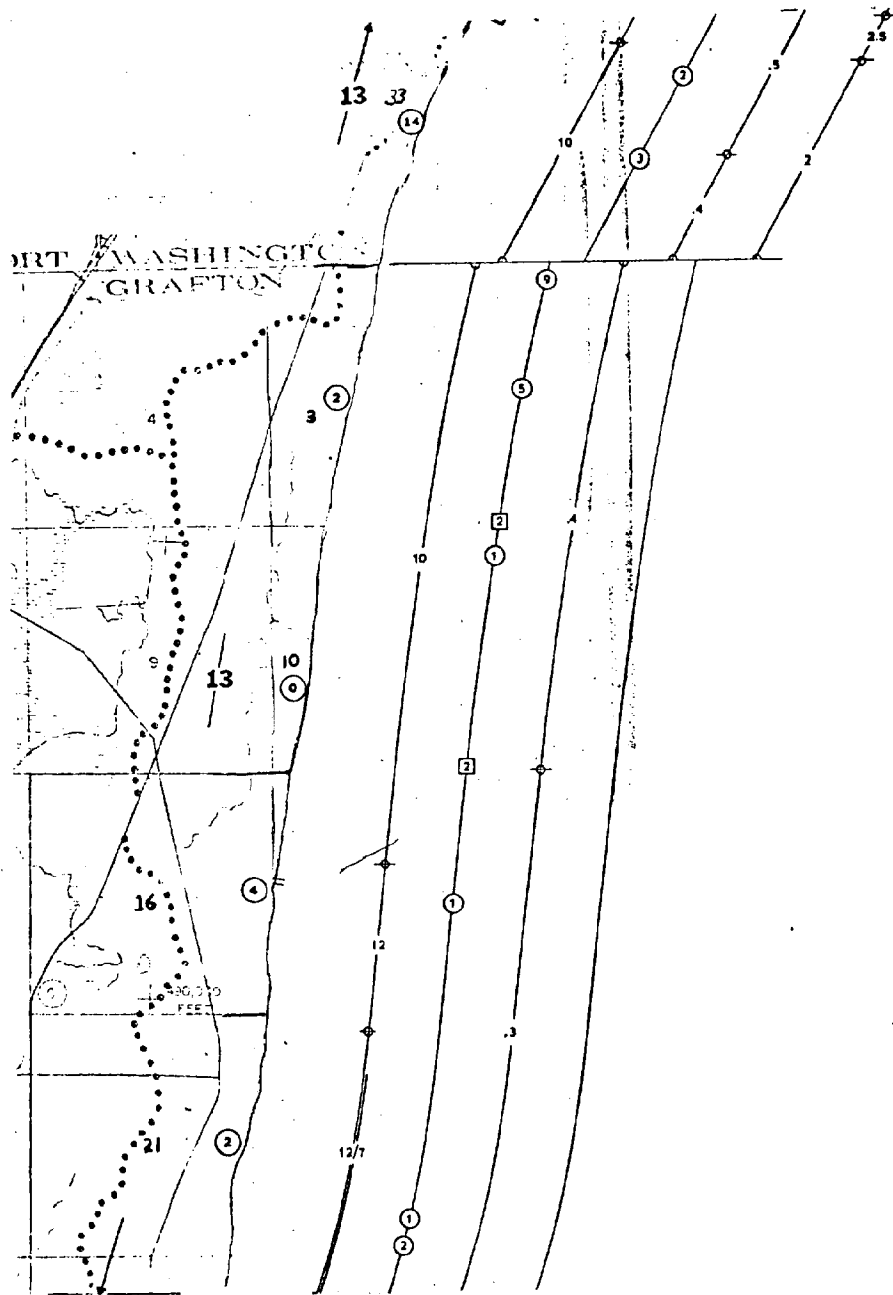
The slope angle in this stretch is approximately 40° . Two major seeps extend the entire length of the stretch with one found in the fine to medium sand layer and the other being found in the gray silt layer. Slope failure seems to be translational sliding (and flow of the red brown till layer) due to undermining by groundwater removal of the fine to medium sand layer. This not only produces undermining, but also provides a fluid medium for the translational failure. Severe wave erosion of the toe of the bluff triggers the failure of the slope. Toe material consists of red-brown till which has flowed over the lower blue-gray till (which is in place).

The second stretch extends from 33.5 to 28.0. As far as can be seen by survey observation, the stratigraphy is the same as that found in profile 1 (33.0) except for the fact that thicknesses may vary. Due to slope failure, no stratigraphy was visible below the top layer which consists of red-brown silty pebbly till as in profile 1.

The vegetative cover in this stretch is markedly increased compared to the first stretch. Vegetation averages approximately 40% throughout 33.5 to 33.9. A very few trees were observed along with weeds and some bushes. From 33.9 to 28.0 vegetation increased to approximately 80% and consisted of many trees with weeds and bushes. No major drainage escarpments were found in this stretch.

Bluff slope was found to be 40° and the conditions were found to be relatively unsatable. Unlike the conditions from 33.0 to 33.5, failure in this stretch seems to consist of minor rotational slumping and flow of till. Severe wave erosion (undercutting) of the toe of the bluff seems to increase failure rate of the slope. Toe material consists of red-brown clayey, pebbly till which has flowed or slumped over either blue-gray silty till or stratified silty clay. No seeps were visible in this stretch, although they could have been masked by the vegetation.

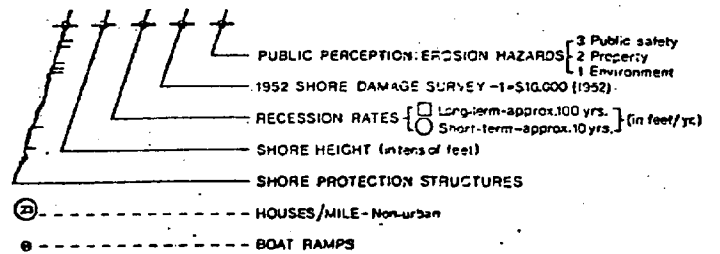
Beach width in this stretch varied between 20 and 30 feet and consisted of intermixed pebbles and sand extending from the water's edge to the toe of the bluff.

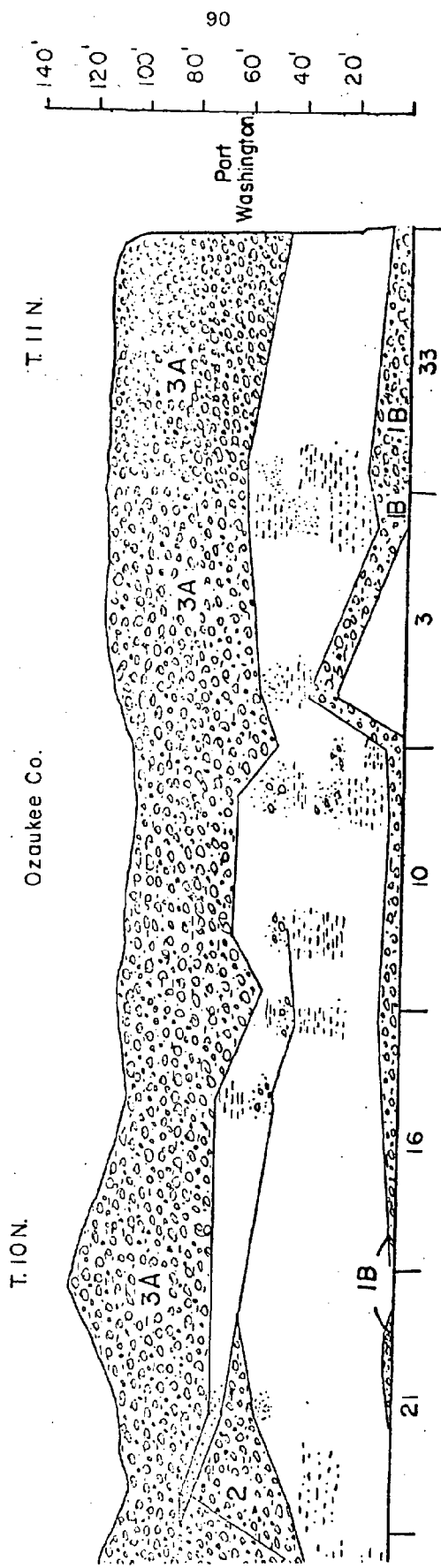


Reach 13

1 mile

N

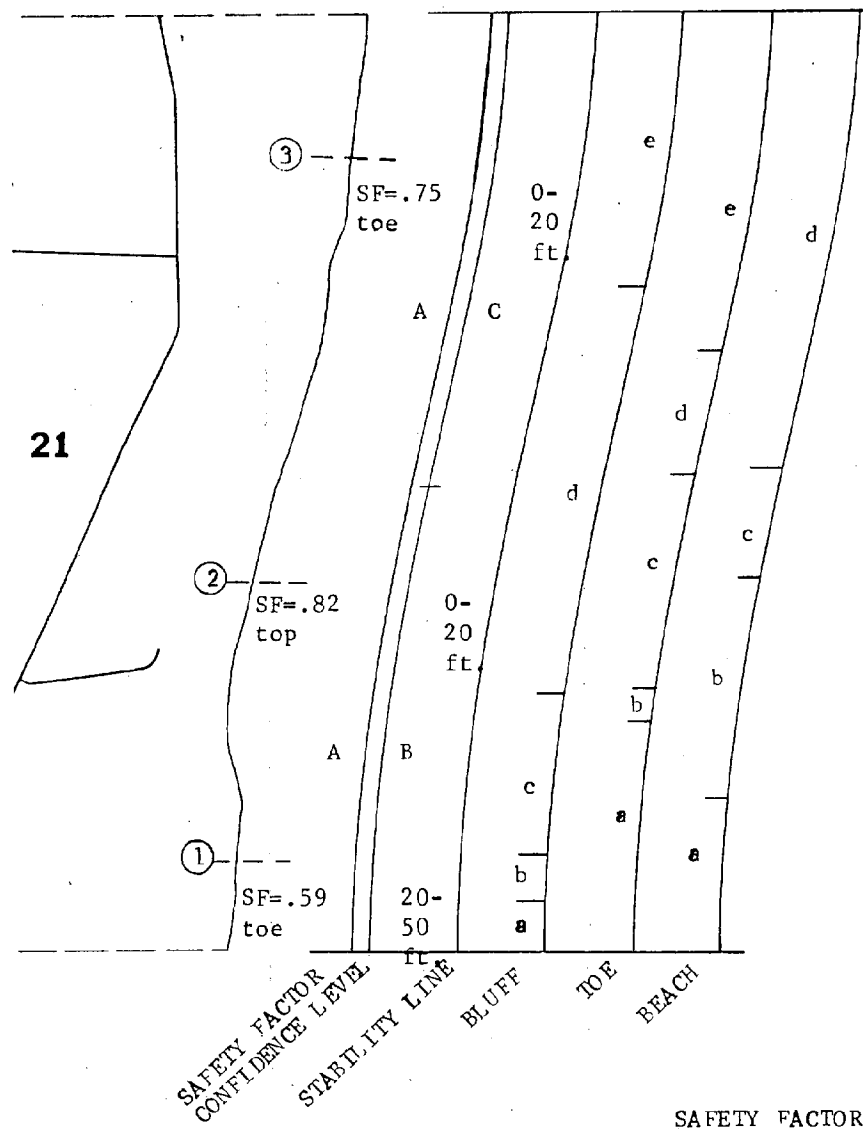




LEGEND

- SAND
- GRAVEL
- SAND AND GRAVEL
- SILT
- CLAY
- CLAYEY SILT, SILTY CLAY
- TILL
- COVERED OR INACCESSIBLE
- MIXED SEDIMENTS

Generalized longitudinal section showing bluff stratigraphy in Reach 13. Numbers along base of diagram are geographic (1 mile) sections.

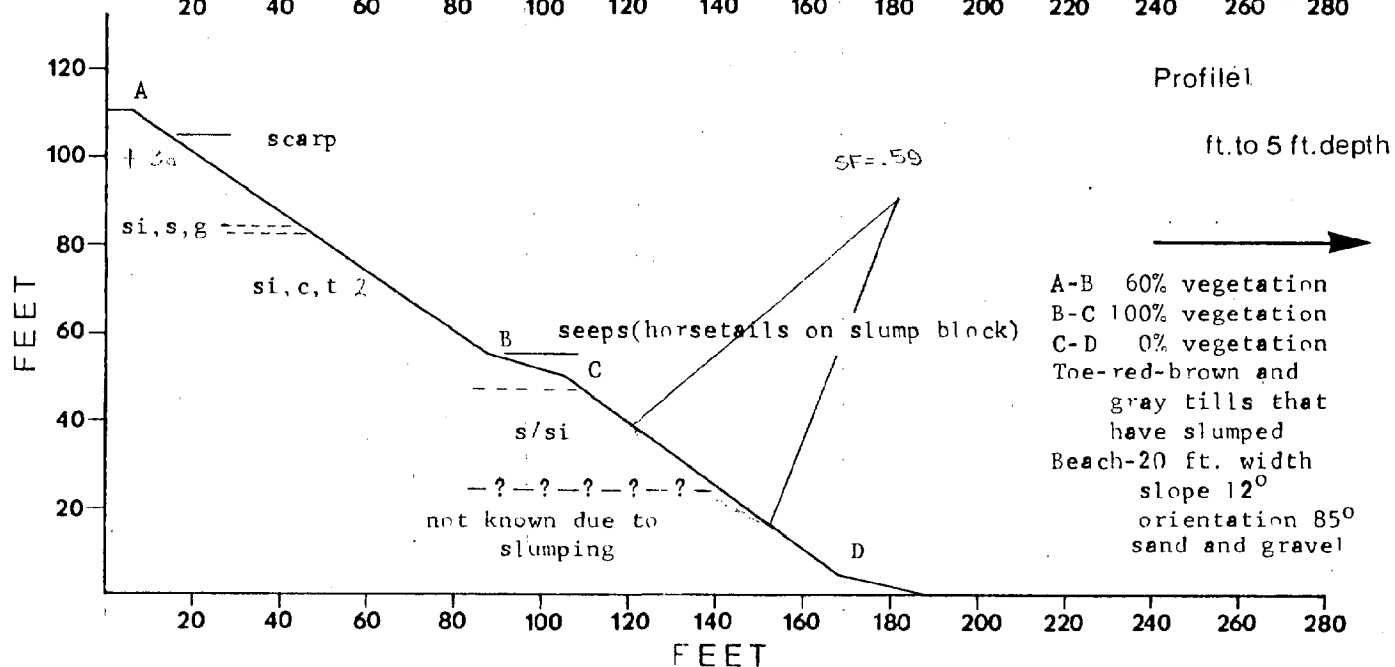
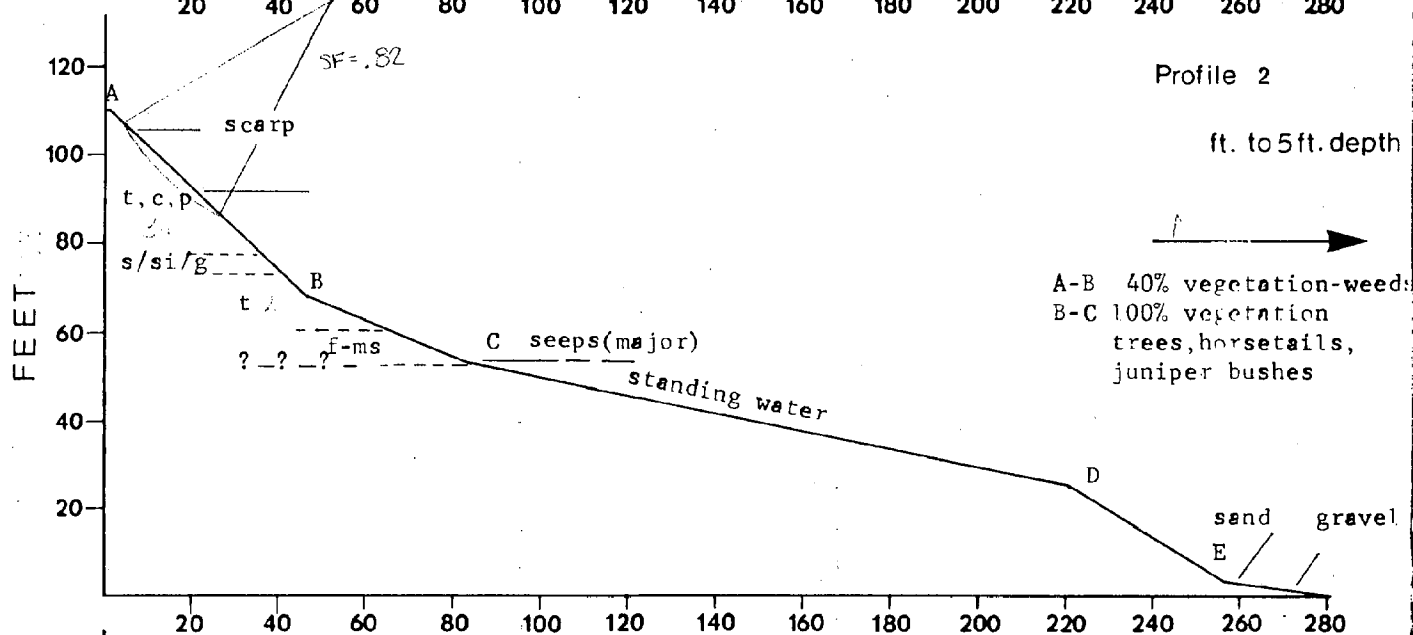
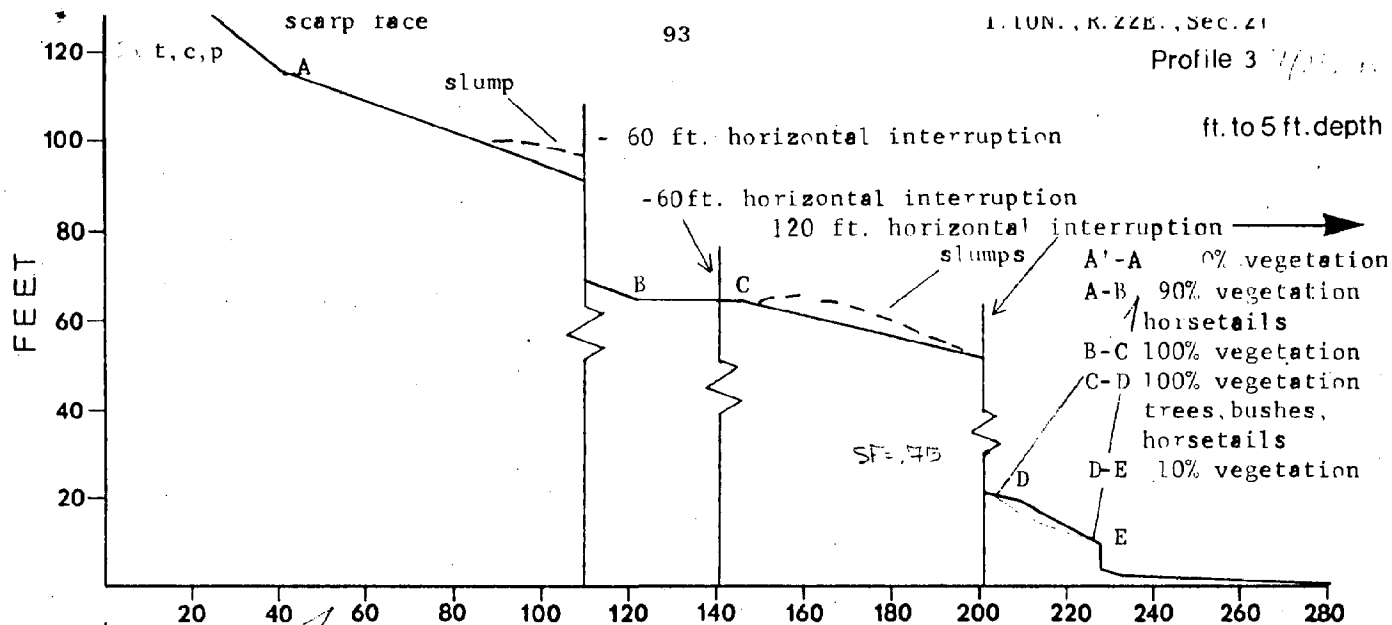
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

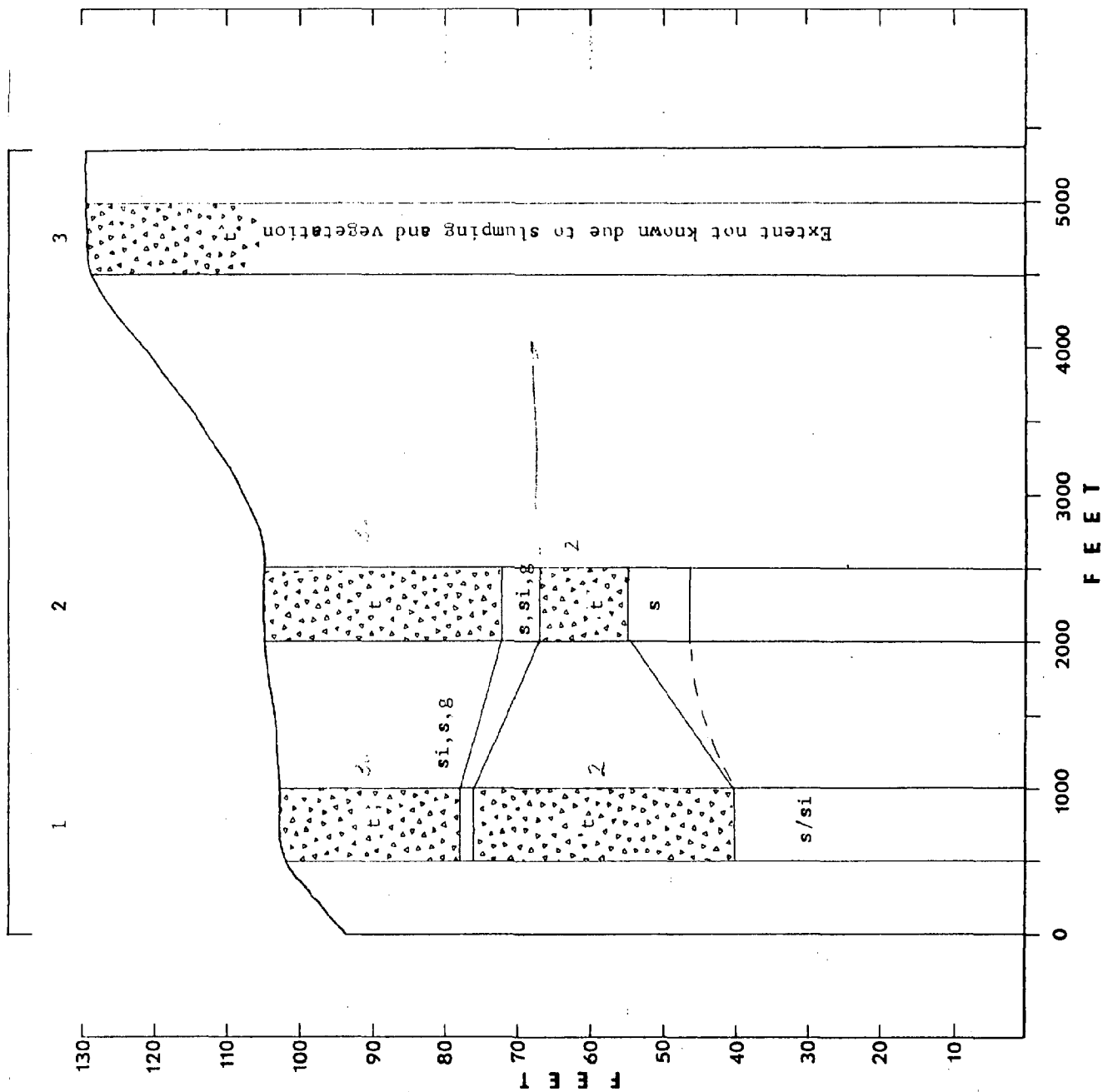
CONFIDENCE LEVEL

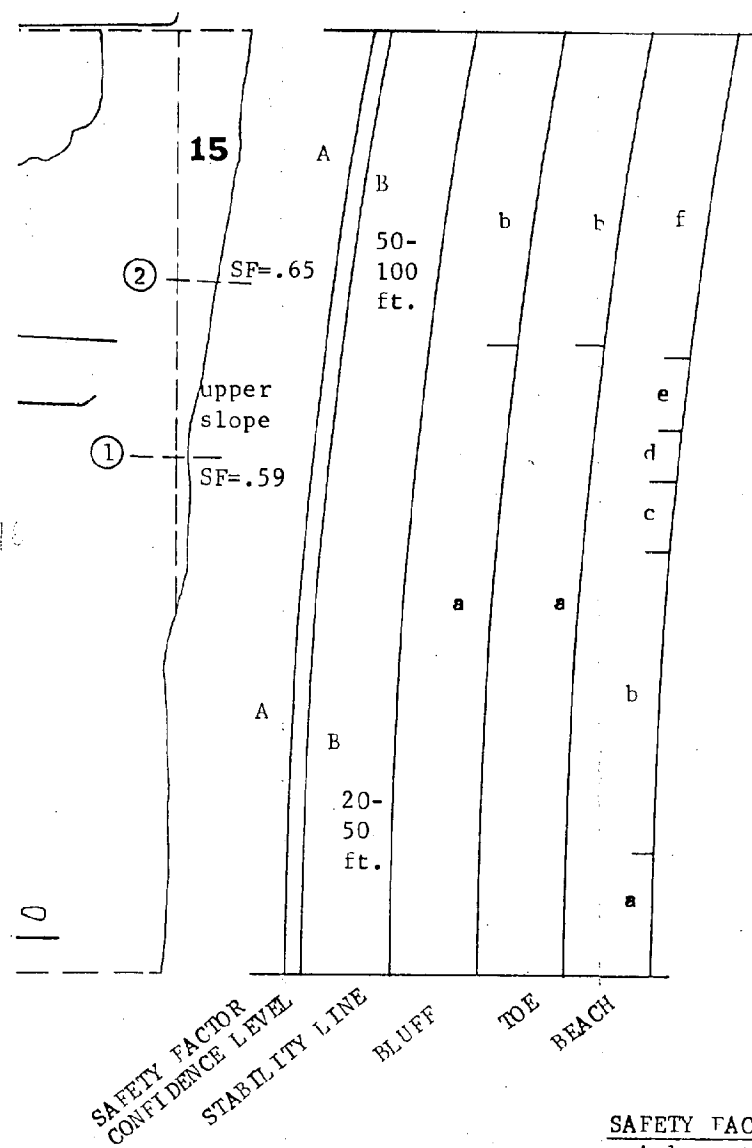
- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low confidence)

1. BLUFF	a-drainage ravine, 100% vegetation, large trees	b-3 successive slump blocks down slope, scarp at top of bluff, 0% vegetation, 35° slope	c-scarp at top of bluff, 100% vegetation on most of bluff (large trees) no vegetation on scarp face and toe of continuous slump block at base of bluff, 30° slope of bluff. Drainage escarpment at north end of this stretch	d-slump scarp continuous at top of bluff, 2 drainage escarpments with 100% vegetation, almost continuous slump block forms the toe of the bluff, 41° slope on bluff face, very unstable, continuous vegetation on the surface of the slump block, no vegetation on the toe where wave action is undermining the toe. Seeps on the toe of slump block.
	e-slump scarp at top of bluff continuous through this stretch, one drainage escarpment with 100% vegetation, 4 successive slump blocks form a large terrace like feature at the base of the bluff, continuous change in slope at top of bluff, terrace-like feature 13 slope, 100% vegetation on top of slump blocks.			
2. TOE	a-blue-gray sandy silty till, overlain by slumped red-brown silty till	b-silt and clay overlain by sand	c-interbedded sand, silt and clay with slumped till overlain.	d-till overlain by sand
	e-gray silty till overlain by red-brown clayey pebbly till.			
3. BEACH	a-10-20 ft. cobbles and pebbles from water's edge $\frac{1}{2}$ distance to toe of bluff, medium grained sand to toe	b-10-20 ft. mainly medium grained sand few cobbles, pebbles and gravel	c-15-25 ft. pebbles, cobbles, gravel from water's edge $\frac{1}{2}$ distance to toe of bluff, medium grained sand to toe.	d-10-20 ft. intermixed pebbles, cobbles, gravel
4. STRUCTURES- none				



T.10 N., R.2 E., Sec. 21



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

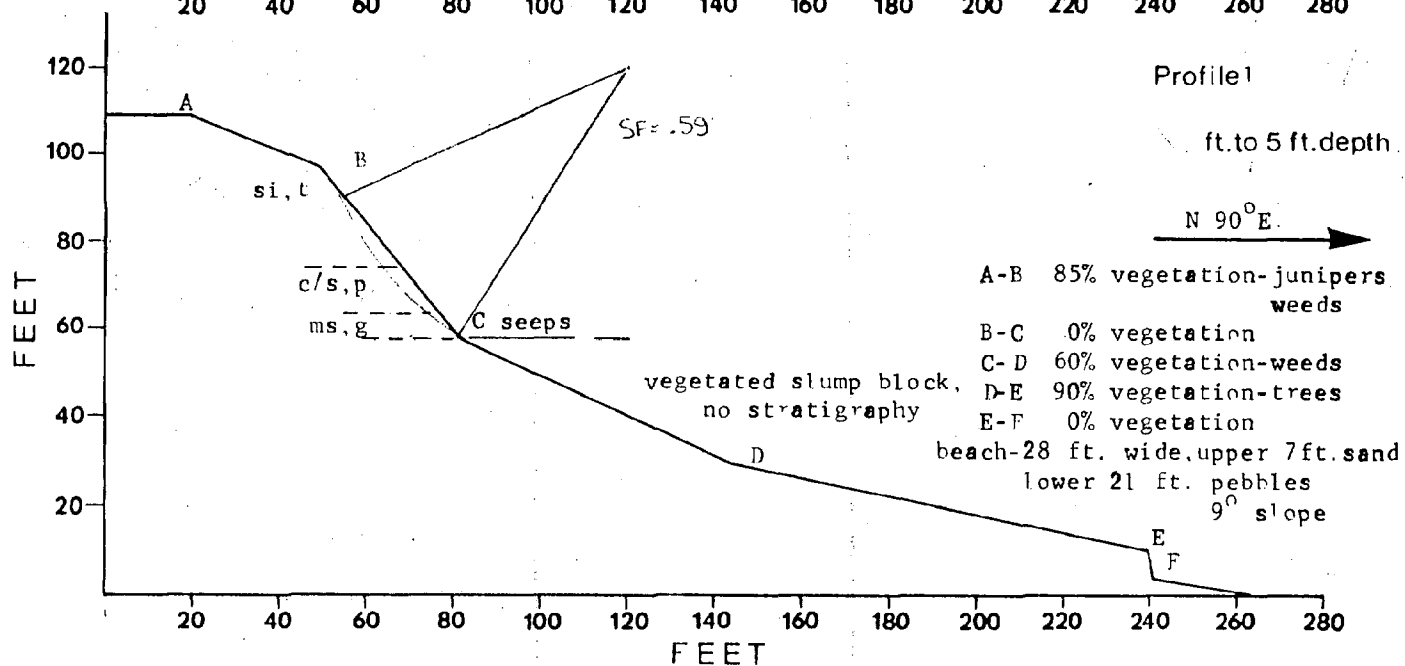
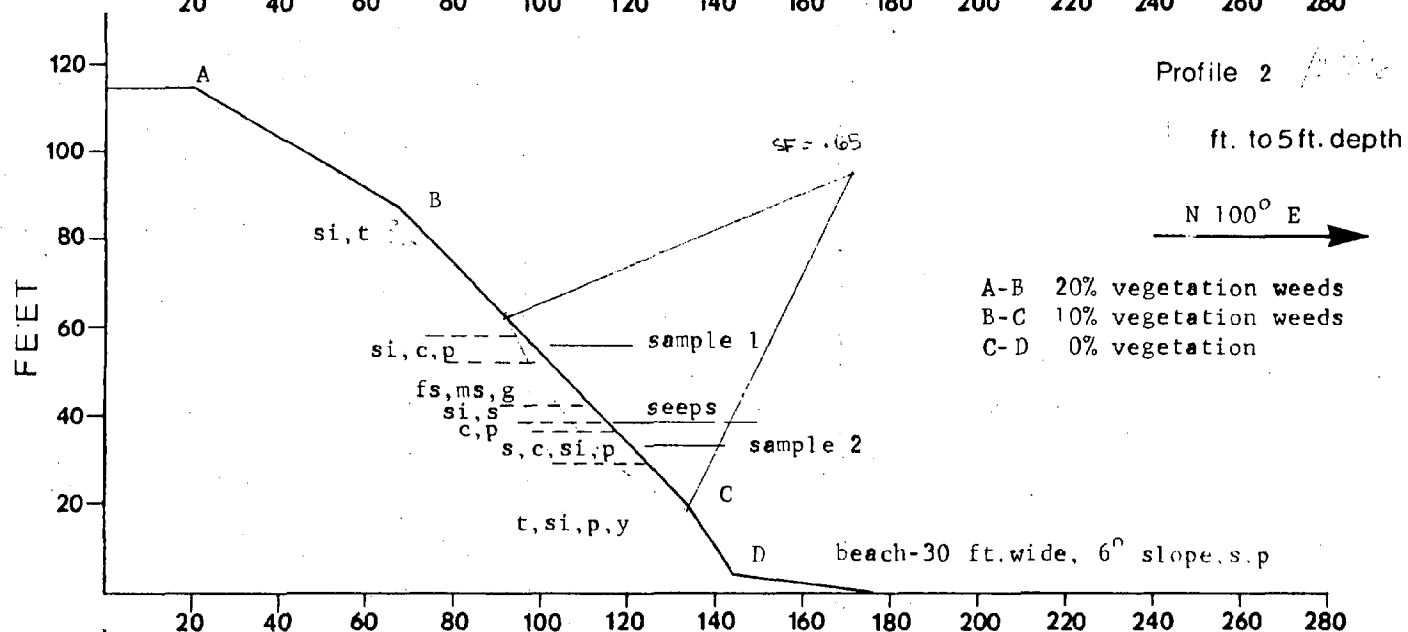
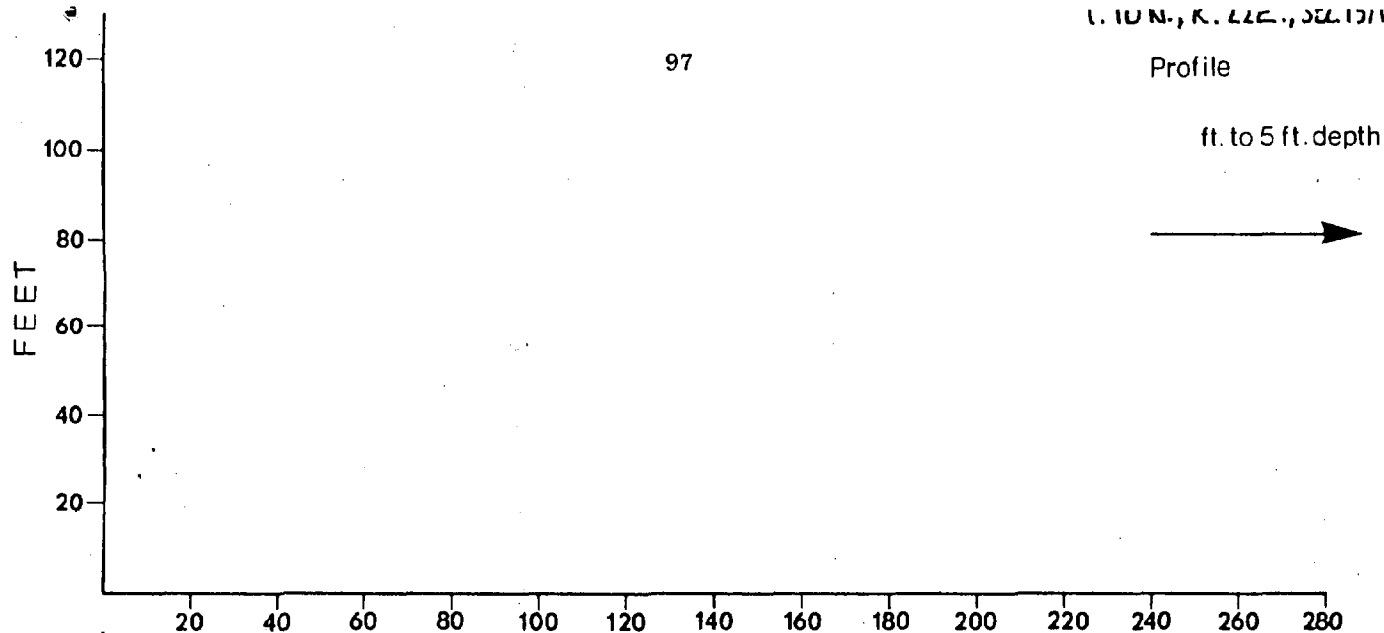
B-near boreholes

stratigraphy visible

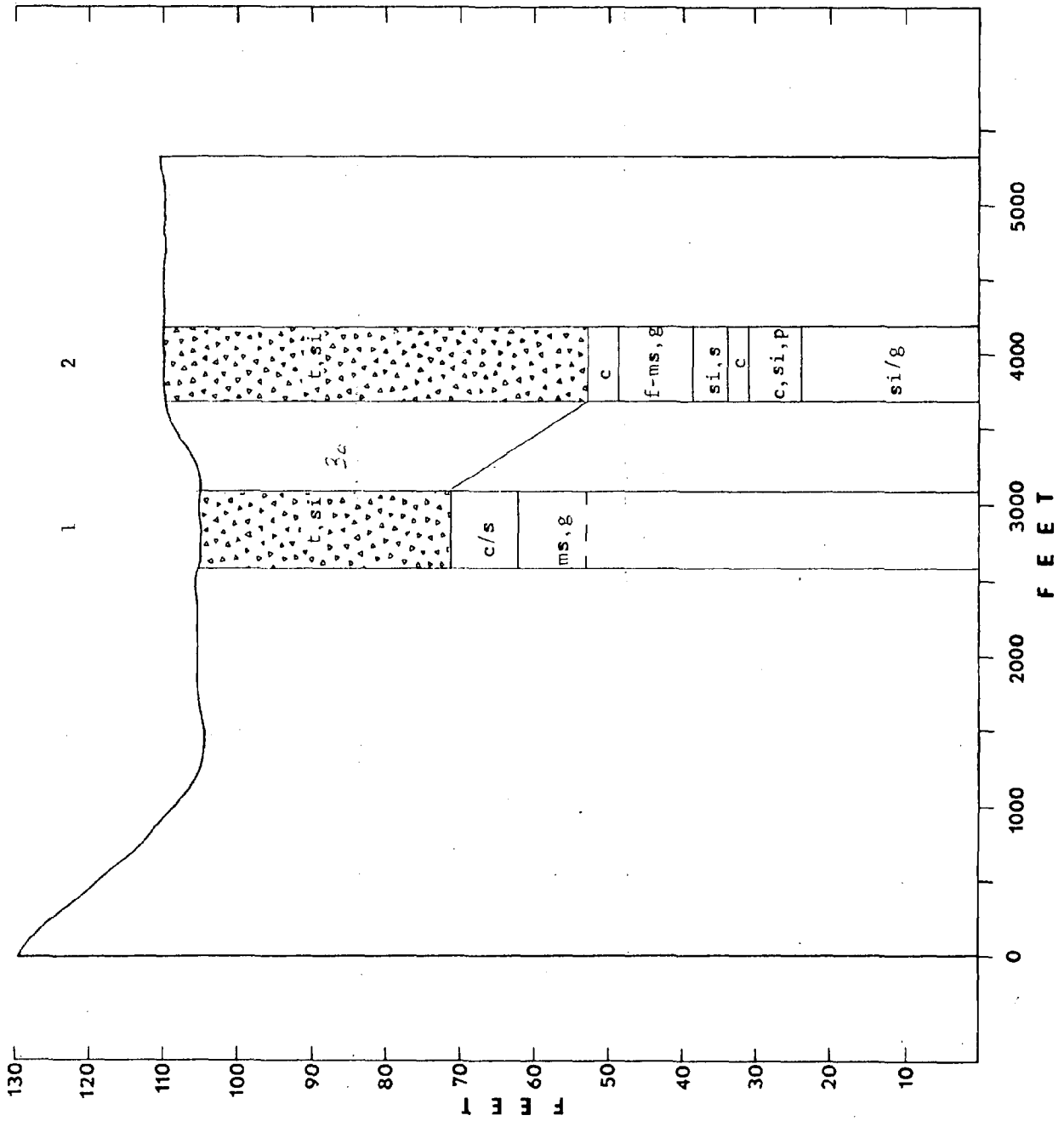
C-no stratigraphy

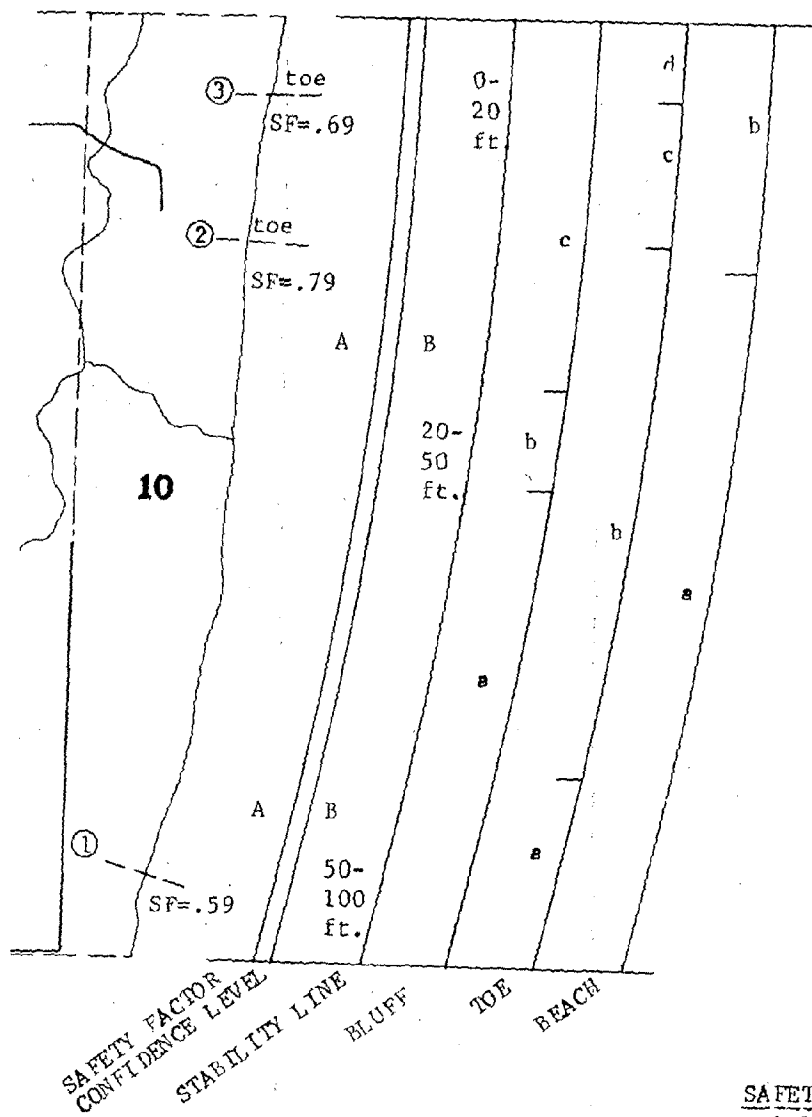
visible (low confidence)

1. BLUFF	a-major deep seated but older slumping zone, no recent failures of any large size.		b-translational slides, rapid toe erosion	
2. TOE	a-slumped red-brown till with sand and silt mixed in.		b-in place till (intermediate) with upper red-brown till flow veneer	
3 BEACH	a- -5 ft., pebbles	b- -20 ft. upper $\frac{1}{2}$ sand lower $\frac{1}{2}$ pebbles	c-5 to 20 ft. pebbles	d- -20 ft. mostly pebble beach
	e-5 to 20 ft. pebbles	b- -20 ft. upper $\frac{1}{3}$ sand, lower $\frac{2}{3}$ pebbles		
4. STRUCTURES- none				



T.10 N., R22 E., Sec. 15/16



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible)

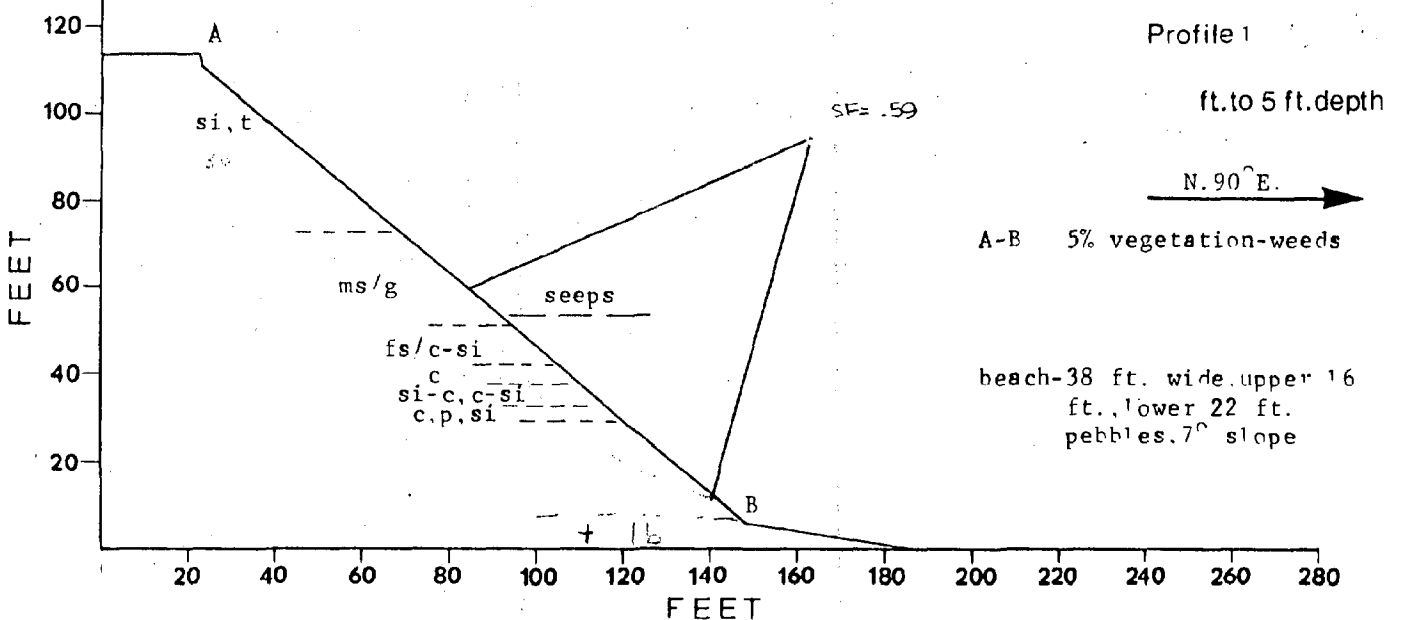
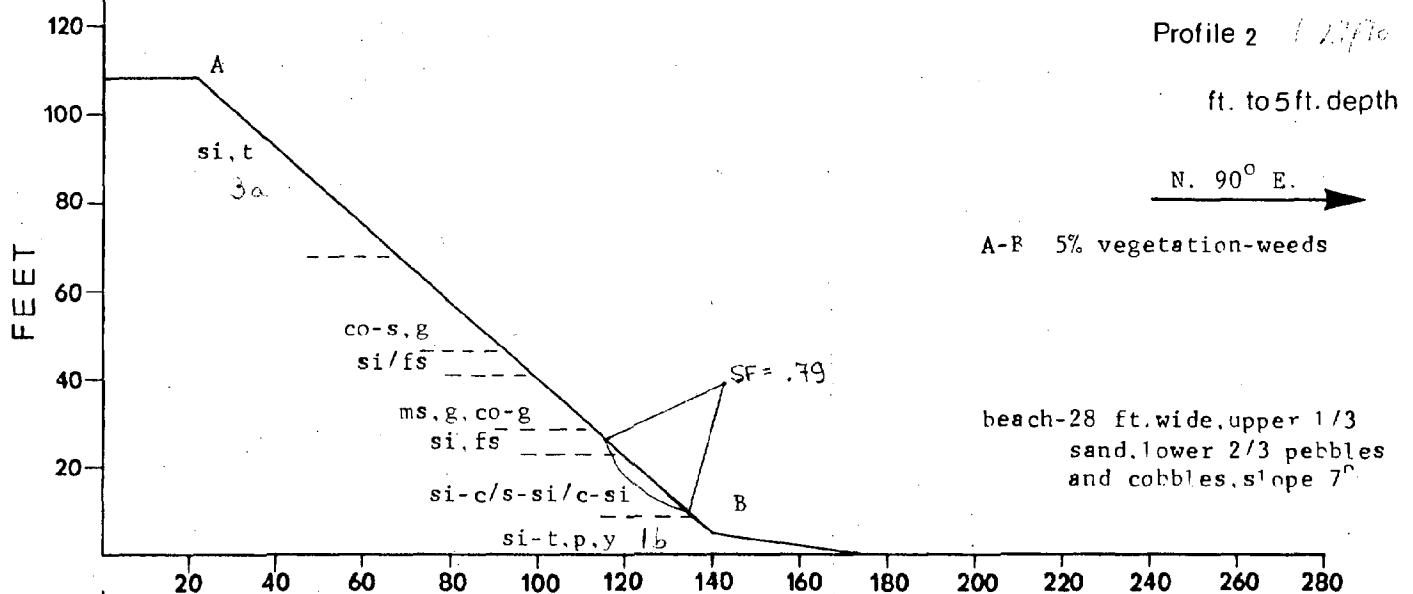
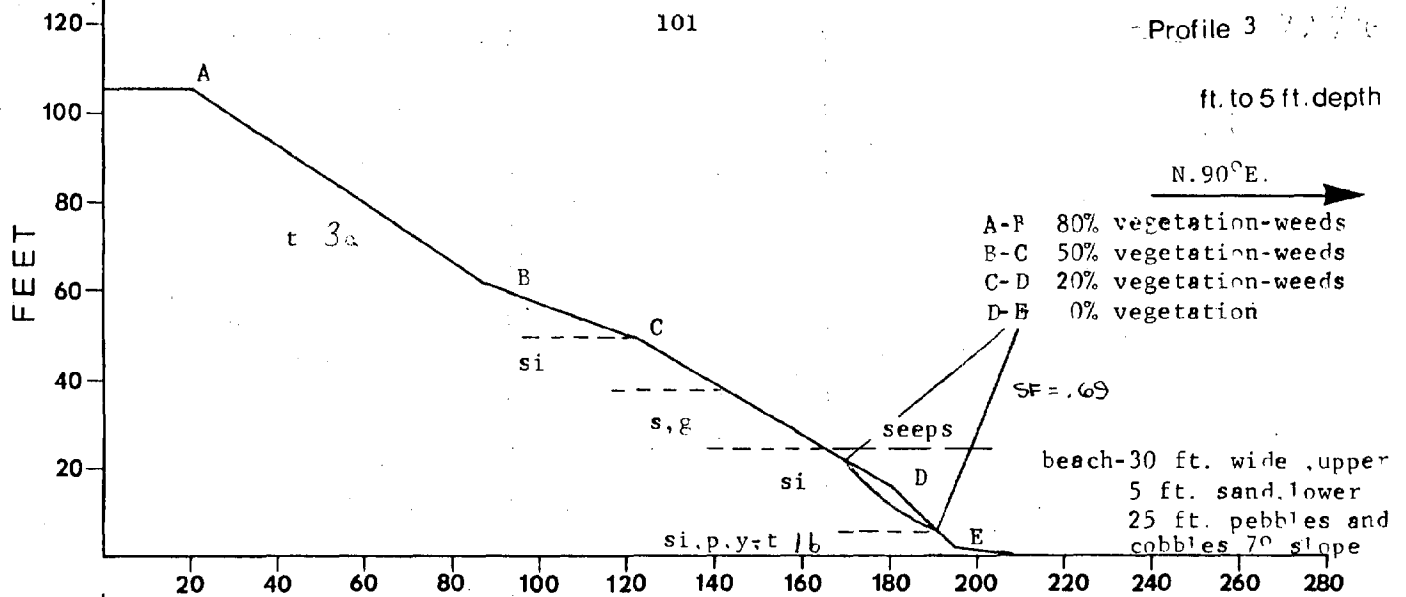
C-no stratigraphy

visible (low confidence)

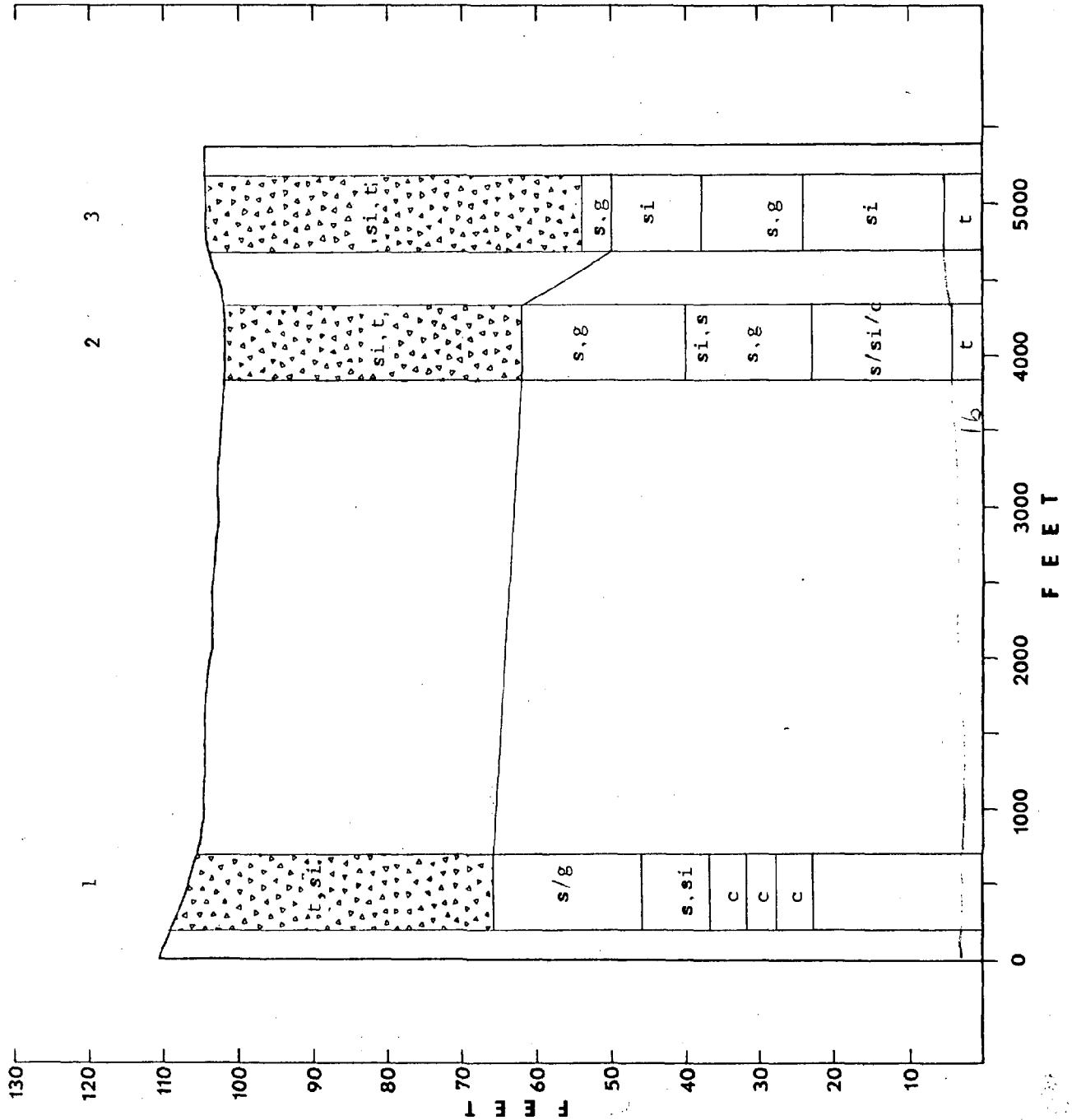
1. BLUFF	a-translational slides due to rapid toe erosion	b-large ravine no slope failures	c-translational slope failures	
2. TOE	a-red brown till, slumped	b-in place silt and lacustrine clays	c-in place intermediate till	d-slumped red-brown till and in place intermediate till
3. BEACH	a-greater than 20 ft. upper 1/2 sand, lower 1/2 pebbles		b-greater than 20 ft., mix of sand and cobbles.	
4. STRUCTURES- none in this section				

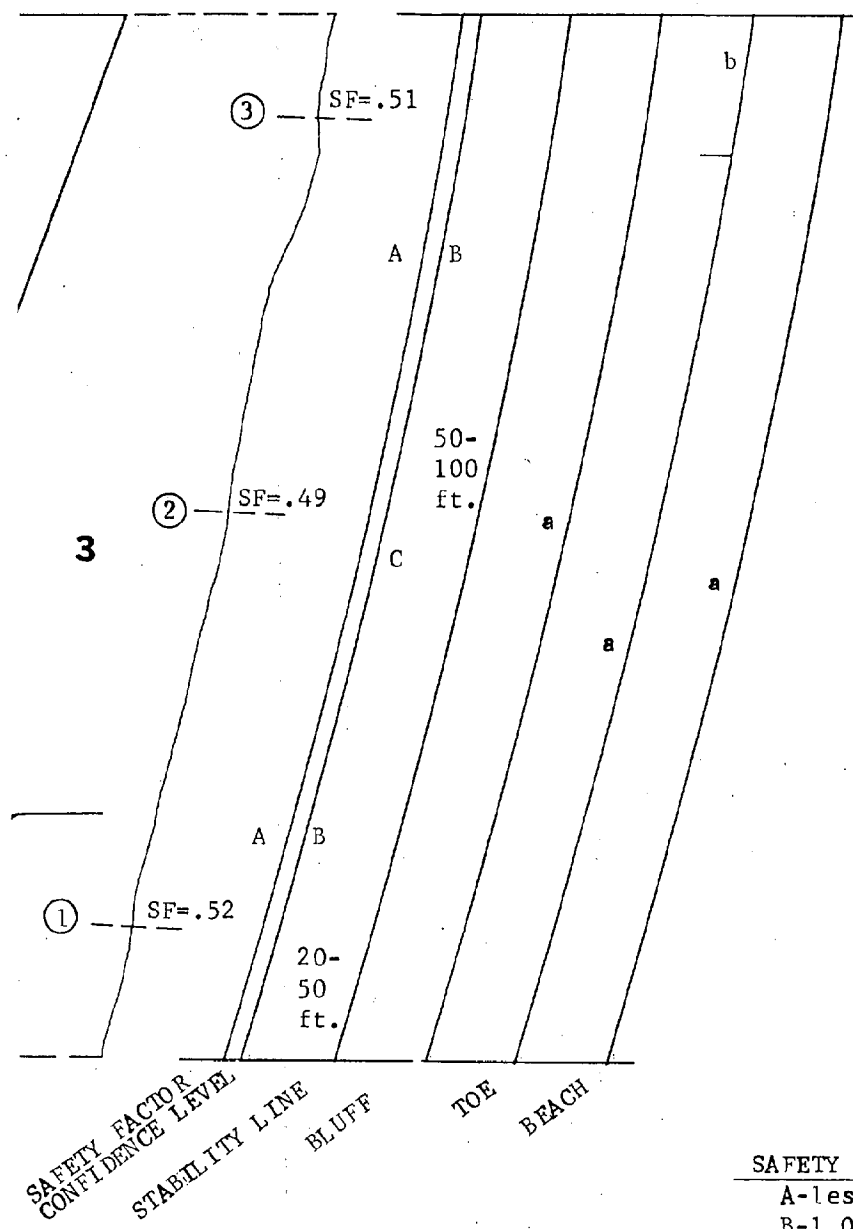
T. 10 N., R. 22 E., SEC. 10

Profile 3 12/76



T.10 N., R.22E., Sec. 10





SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

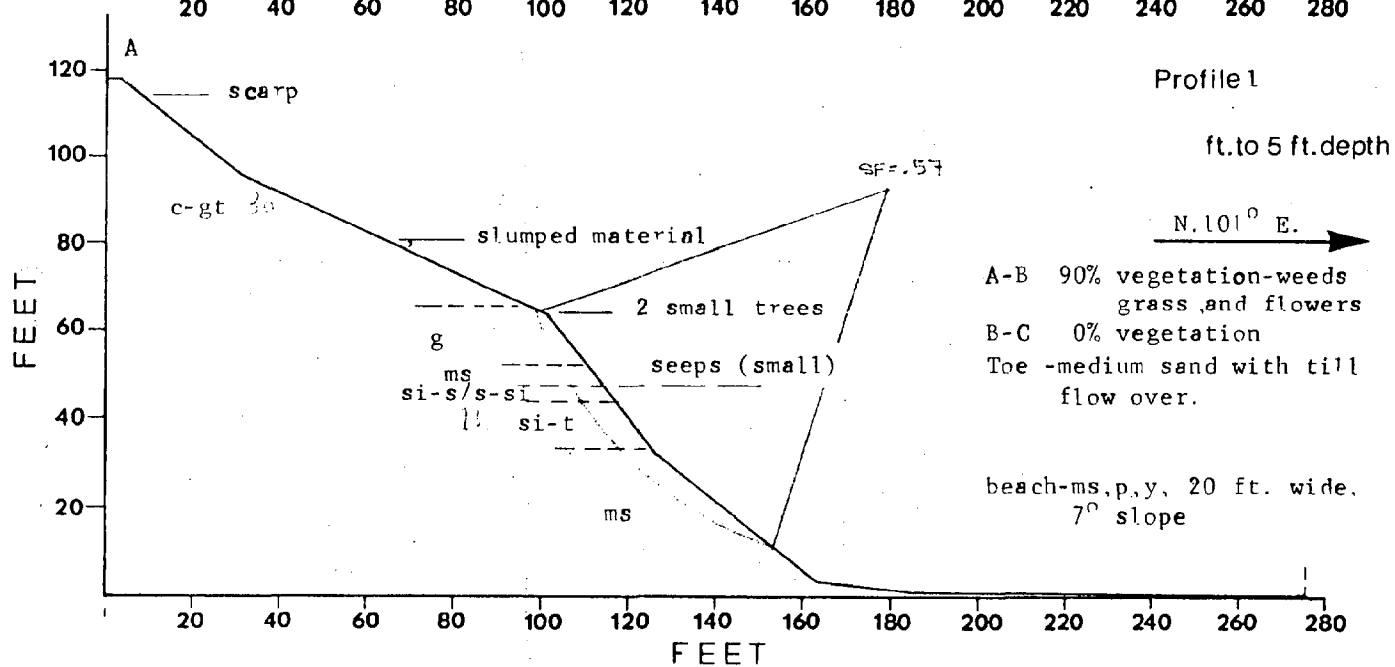
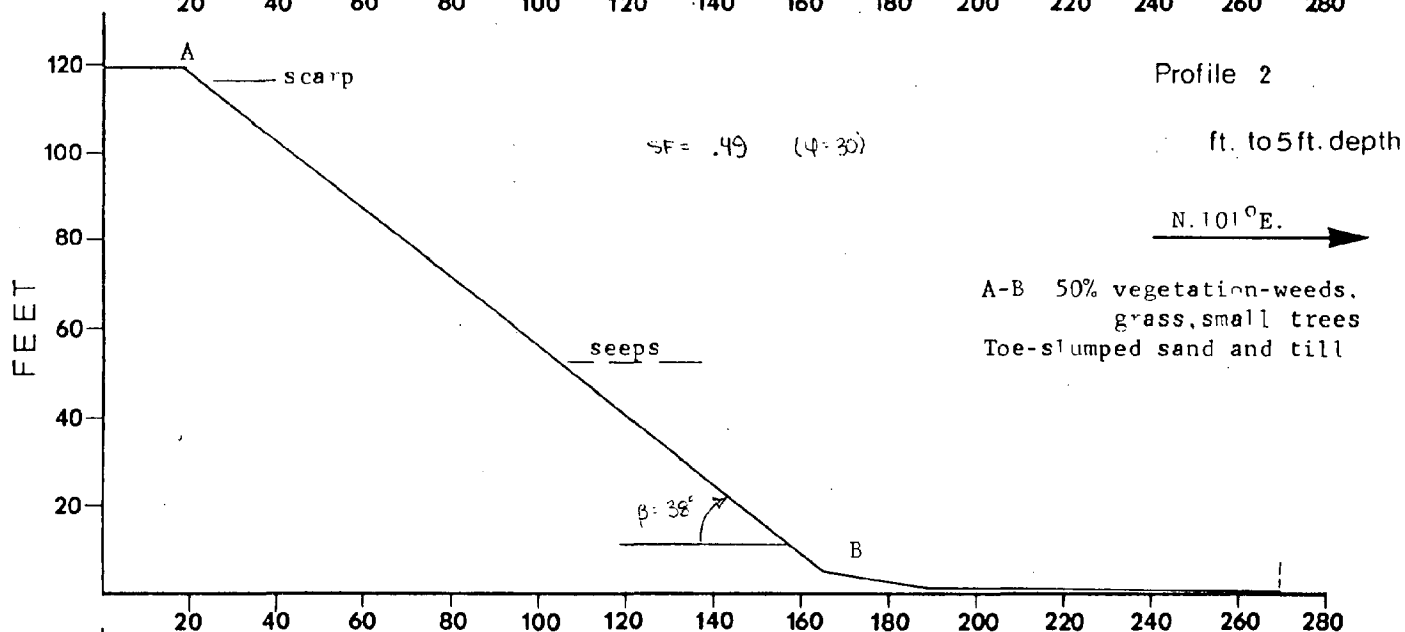
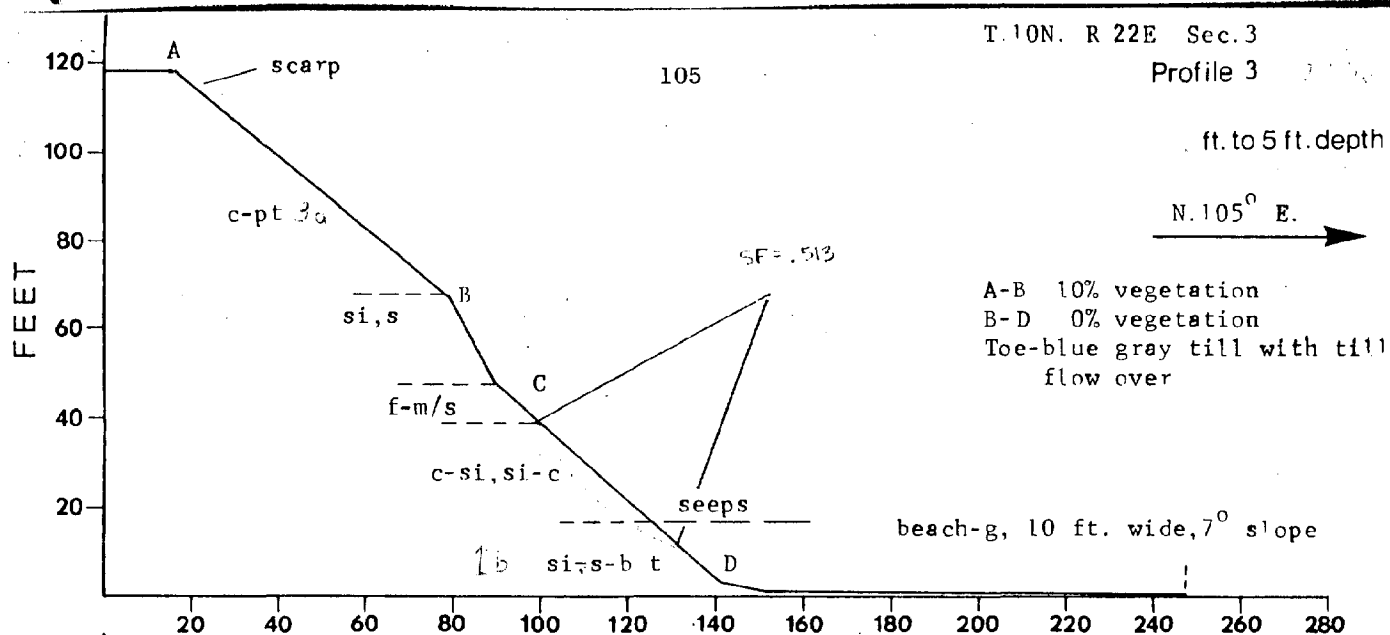
(stratigraphy visible)

C-no stratigraphy

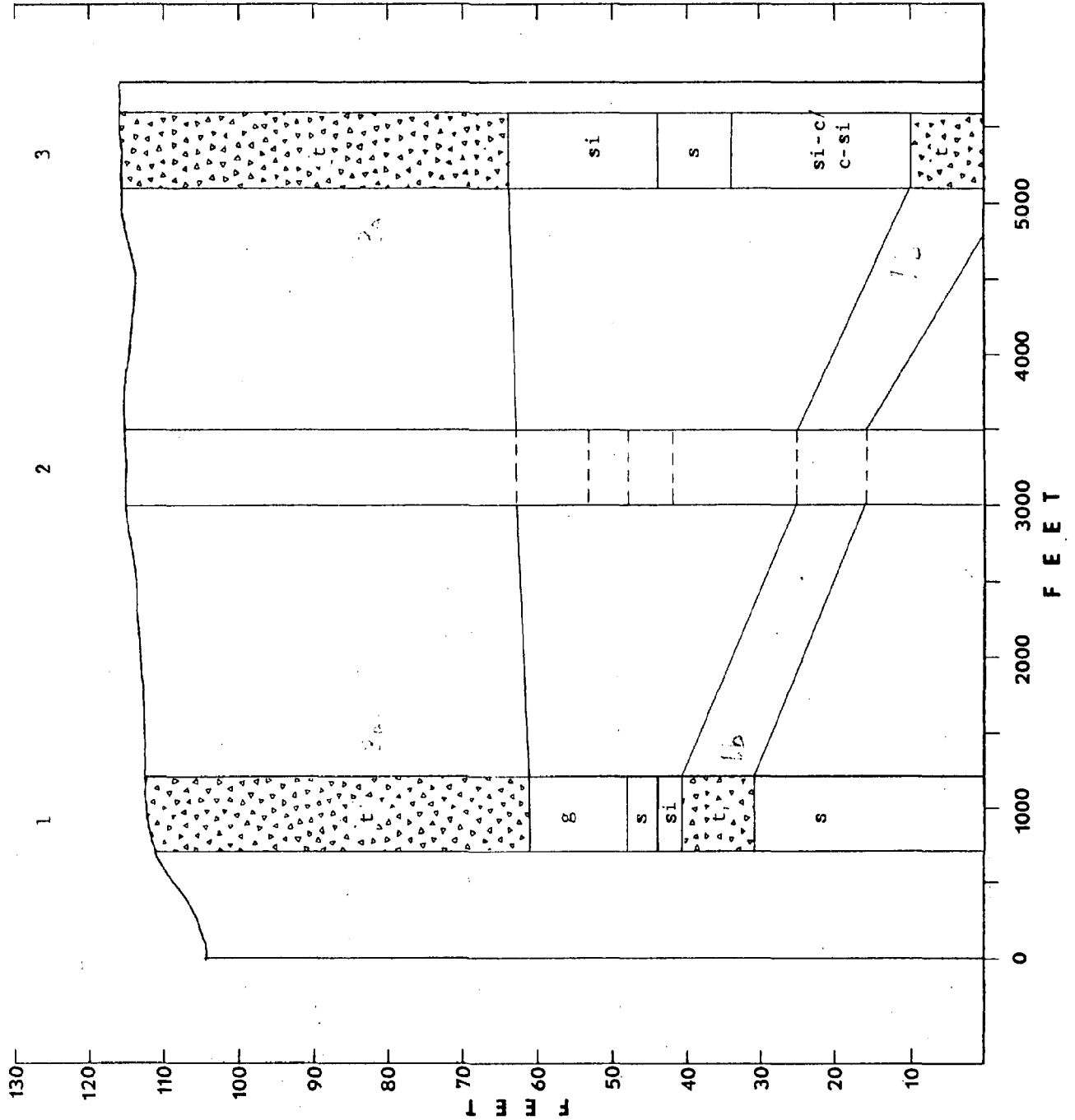
visible (low

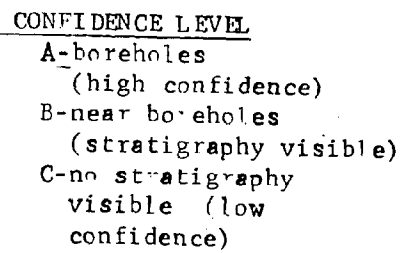
confidence)

1. BLUFF	a-scarp at top of bluff continuous throughout the section except at the locations of the drainage and runoff escarpments. Vegetation is sparse throughout the section, except at the locations of the escarpments. Bluff failure seems to be translational movement of material aided by groundwater sapping. Slope angle averages 40° throughout the section. Severe wave erosion of the toe is evident in many places.	
2. TOE	a-medium grained sand with flow till (red-brown) covering in places.	b-blue-gray till with red-brown flow till covering in places.
3. BEACH	a-beach width 10-25 ft., pebbles, cobbles and gravel at the water's edge grading into medium grained sand which continues to the toe of the bluff.	
4. STRUCTURES-	none this section	

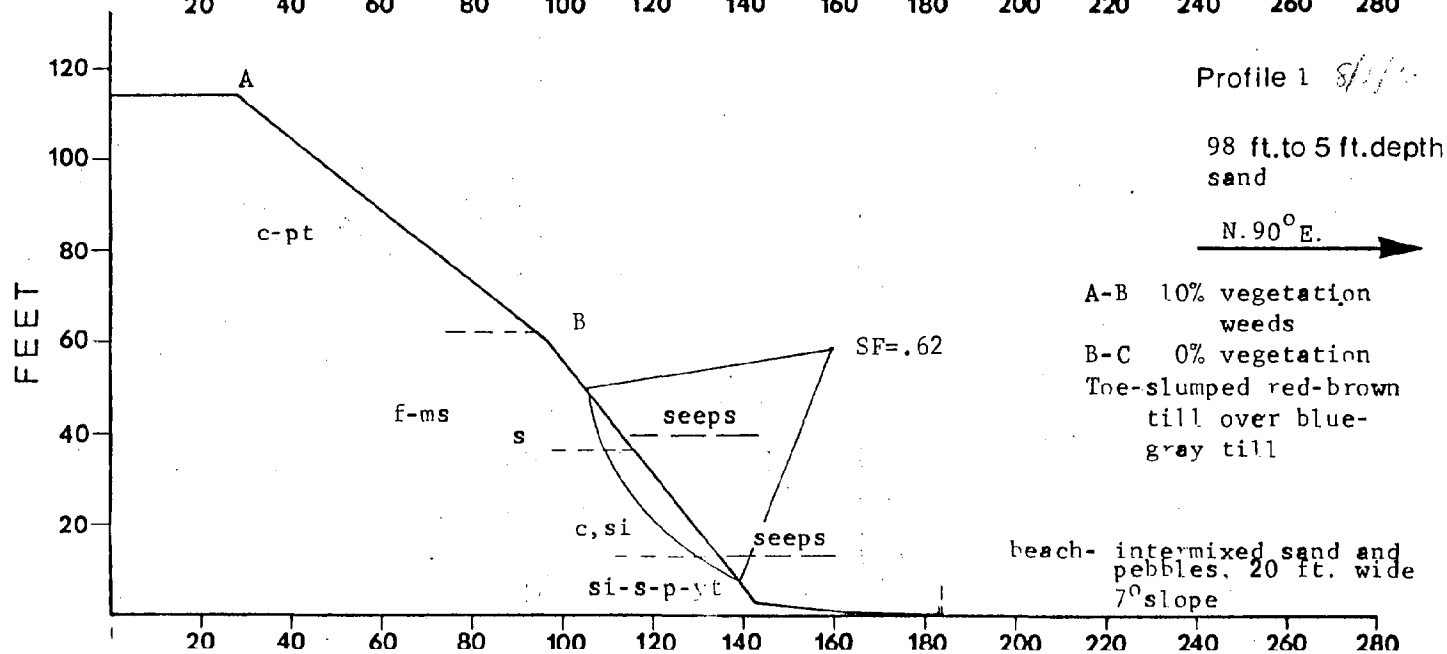
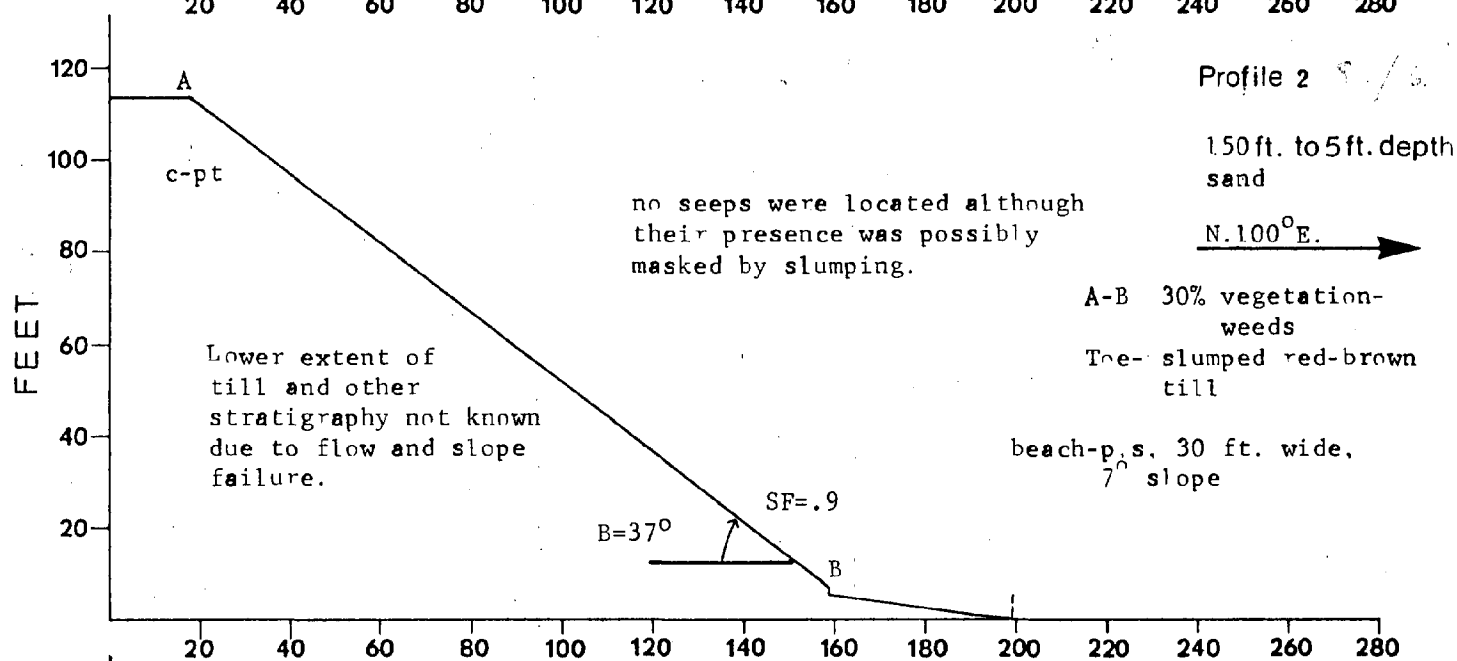
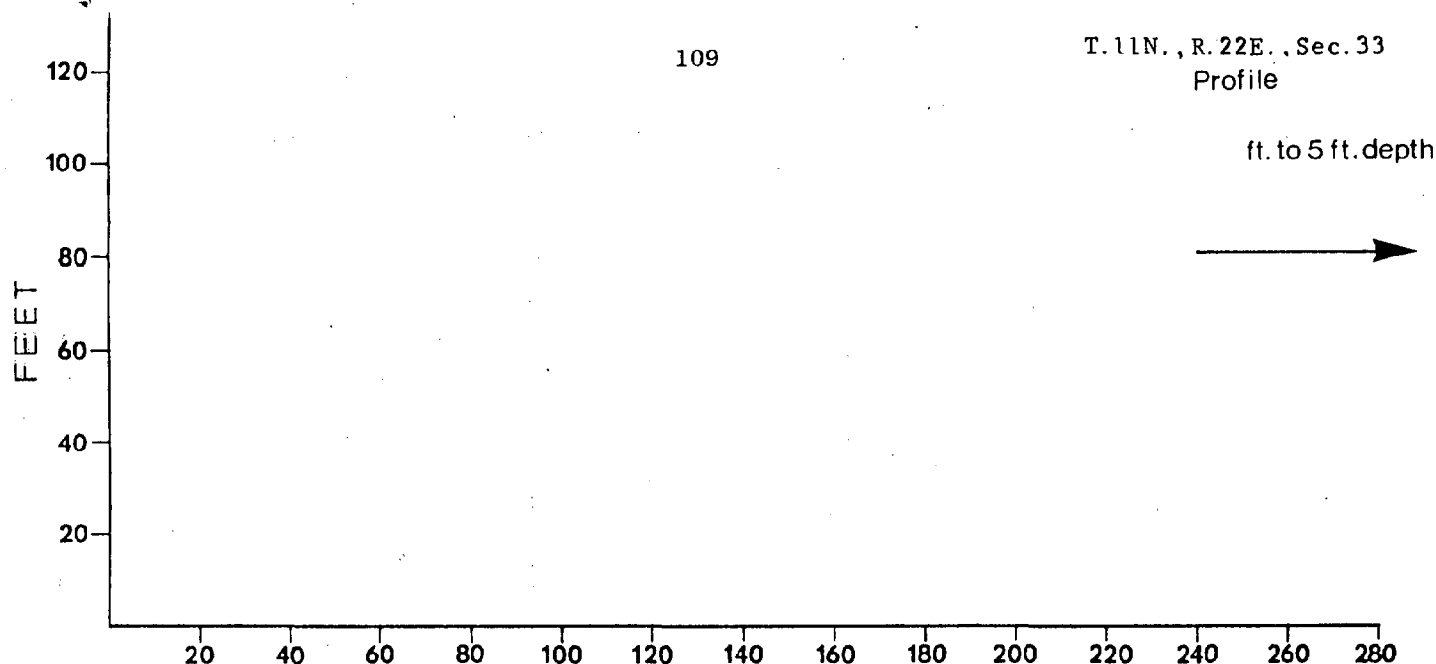


T.10 N., R.22E., Sec. 3

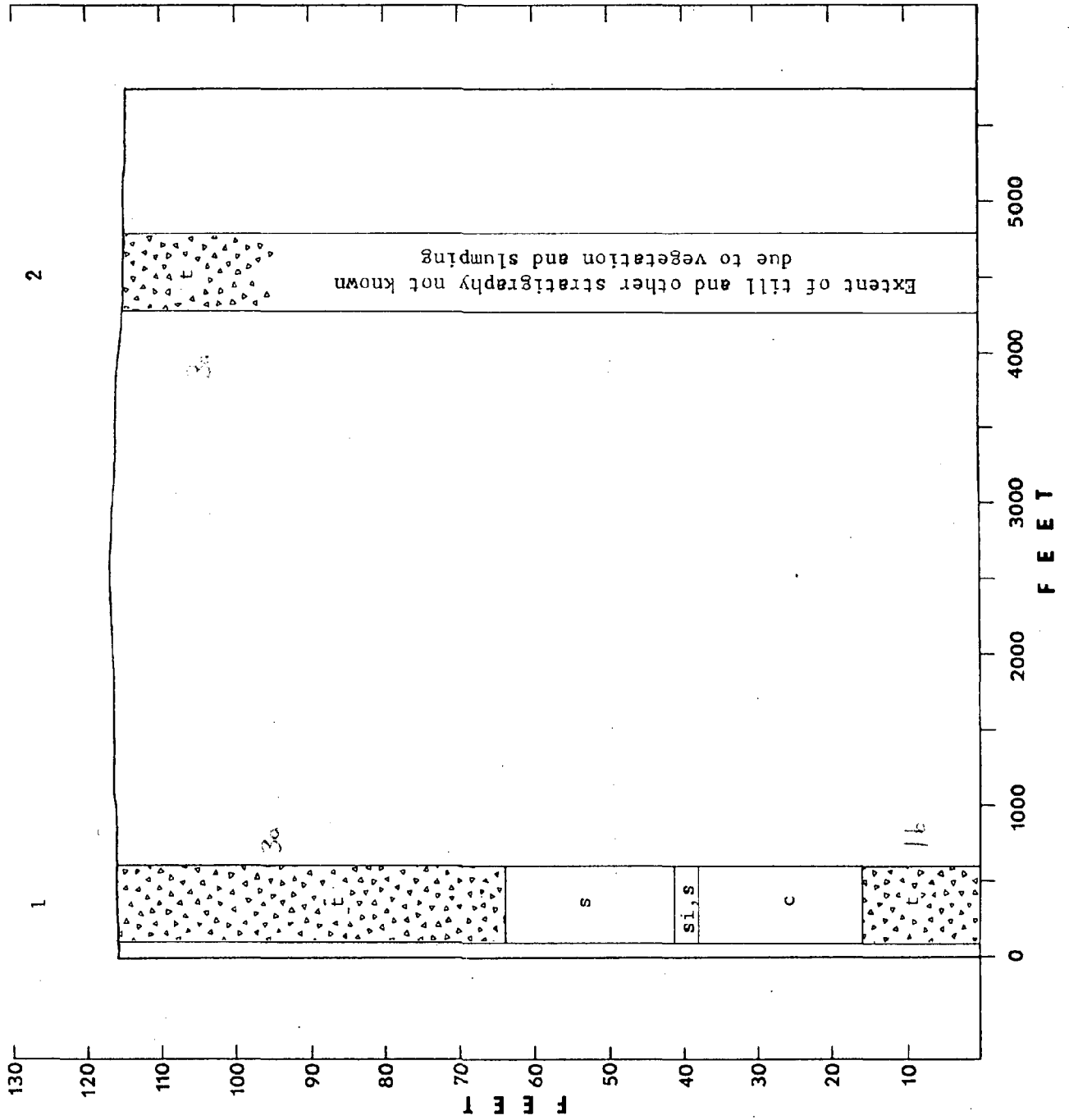




1. BLUFF	a-unstable bluff, 7 drainage escarpments, translational failures of material, minimal vegetation, most areas no vegetation at all. 40° slope with excessive undercutting of toe material by wave action. Two major seeps continuously through the stretch, failure scarp at top of bluff.	b-unstable bluff, rotational slumping of material. 40% vegetative cover for most of stretch. Slump scarps at top of the bluff continuously through stretch. Toe material is slumped red-brown till, excessive undermining of the toe by wave action.
2. TOE	a-red-brown clayey till over blue-gray silty till or over stratified silty clay.	
3. BEACH	a-beach width 20-30 ft. with intermixed pebbles and sand extending continuously from the water's edge to the toe of the bluff.	
4. STRUCTURES-	none this section	



T.11 N., R.22 E., Sec.33



Reach 15

Location

Reach 15 is located in Township 11 North, Range 22 East in central Ozaukee County. The reach is about 4.5 miles long and extends northward from the Port Washington structures to a lake terrace in section 1, T. 11 N., Land use of the bluff top and terrace is either residential, farm land, or forest.

Reasons for Criticality

Reach 15 is ranked 15th on the Erosion Problem Area priority list having a value per mile of 10. This value is based on (1) the short term recession rate that varies from 3 to 8 feet per 10 years; (2) the erosion Hazard Perception value of 2 to 3.5; and (3) the 1952 shore Damage Survey value of 0 to 3.1.

General Conditions

Reach 15A

Reach 15 is divided into two parts on the basis of the type and severity of the erosion. The southern part, designated 15A, is an area of slumping which exhibits extremely high recession rates. This area extends from the Port Washington Harbor protective structures north to the section line dividing section 28 from section 22.

Section 28, T. 11 N.

Section 28 is the section that contains most of Port Washington. It encompasses all of reach 14 and reach 15A. The land in the reach 15A part of section 28 is used for Lake Park.

In section 28 (from 28.7 north to 28.82) is the most severe erosion observed in either Milwaukee or Ozaukee Counties. The failure type in this stretch is rotational slumping, however the slope differs from other slumping zones in that the parabolic failure plane is almost vertical in its exposure on the bluff. Each individual failure does not remove much material from the bluff but the

failures are frequent so the bluff top is retreating rapidly. A topographic profile across this area (from 28.7 to 28.82) shows a narrow sand beach, a mass of slump debris with a vertical wave cut toe and gently rising surface, behind the slump debris pile is the nearly vertical bluff face. The slope has zero percent vegetation and the surface of the slump block instead of being smooth is very rough. This indicates that the debris is the result of several failures not just one large failure. The grass and soil at the bluff top overhangs the edge by 2 or 3 feet in places.

The stratigraphy immediately north of the waste water treatment plant finds the first in-place red lacustrine silty clay 12 feet above the beach. This layer is 10 feet thick and overlain by 4 feet of fine sand with some interbedded silt and 2 feet of medium buff sand. Over the sand is 6 inches of silt and red brown silty till extending to the bluff top. Numerous seeps are located in the more permeable fine sand layer (over the less permeable red clay).

At 28.8 the beach texture changes abruptly from all sand to all cobbles. This change coincides with the exposure of a silty pebble cobble till at the toe of the bluff.

North of 28.85 the erosion is not quite as rapid and conditions are like those portrayed in profile 1. Profile 1 located at 28.87 is an area of shallow slumps near the bluff top with the sliding of the material in one mass down the slope. As the mass slides down the bluff face it smears a veneer of debris across the surface. The topographic profile has a steep 3 foot toe followed by a very long uniform slope of about 32° . At the very top of the bluff is a slightly steeper scarp (48°). This picture of the profile is not entirely accurate because the long straight B to D slope is very hummocky.

The stratigraphy exposed in this profile has the same units as just described but they are found higher in the bluff. At the toe and responsible for the steep toe is a silty pebble cobble till of which only 3 feet is visible. Above

the till a veneer of red brown till obscures the stratigraphy for 26 vertical feet. At this point a red silty clay is located. Over the clay is about 9 feet of fine sand and 4 feet of medium sand. These thicknesses represent a gain in total thickness for the sand layers of 7 feet from the exposure north of the waste water treatment plant. On top of the sand is a red brown silty till layer about 54 feet thick. Minor seeps are noted in the sand at the sand-clay contact.

Reach 15B

The northern part of reach 15 is differentiated from the southern part by the lower recession rates present, and by the slightly different slope failure type. In reach 15B, slope failure in the southern 1/3 is by slumping on the upper bluff slopes and by sliding on the lower bluff. The northern 2/3 of reach 15B is characterized by translational sliding only.

The bluff height of reach 15B decreases northward from 116 feet in section 22, T. 11 N., to 85 feet in the central sections of the reach and 50 feet at the northern end of the reach.

Within the reach are three areas of old lake terrace. The largest occupies the middle of section 14/15. The other area totally within the section is in section 11. The final area of terrace is in section 2/1. This area extends through the next several reaches.

The stratigraphy of the reach is rather uniform. At the base of the bluff in most localities is a silty gray till with many cobbles and pebbles. At the top of the bluff throughout reach 15 is a red brown silty pebbly till. Sandwiched between these two tills is a variable sequence of lacustrine, and fluvial, silts, sands, and gravels. The thicknesses of the units change greatly depending on the location but in general the lower gray silty till increases from 4 feet at the southern reach line to about 27 feet thick in section 22. In the northern 1/2 of the reach the lower gray till is not exposed. The separating fluvial lacustrine sediments are generally about 40 feet thick, with most of this thickness

(about 30 feet) being silts in the southern 1/2 of the reach and most being gravel in the northern 1/2 of the reach. In many places the gravel layer was highly cemented (with silicious material) to a very hard, dense conglomerate.

The upper red brown till varies in thickness with the bluff height being thickest (40 to 50 feet) in the highest bluff area (sections 28, 22). In the northern 1/2 of the reach the thickness is on the order of 30 to 40 feet.

The beach width varies greatly, from over 70 feet wide in section 22 down to 5 to 20 feet wide in many of the areas. The average wide value is best expressed on the section maps. The composition is generally coarse grained pebble and cobble beaches despite the presence of many sand areas.

The vegetative cover through the entire reach is very thick. This, coupled with the slumping type failure, made stratigraphy difficult to obtain.

Section 22, T. 11 N.

Section 22 is a high bluff area subject to a combination of slumping and sliding. Land use of the bluff top is entirely residential. Best access to the bluff and beaches is by way of Lake Park on the southern section line and a dead end dirt road on the northern section line.

The southern 1/3 of section 22 is an area of slumping near the bluff top and sliding on the lower slopes. The instability of this area can be attributed to the narrow 5 to 25 feet sand and cobble beach. The narrow and coarse grained beach can in turn be attributed to the focusing of currents and wave action on the area by the jetties protecting Port Washington Harbor. Profile 1, measured at 22.02, is typical of this stretch of bluff and shore.

In profile 1 the beach is 15 feet wide and made primarily from cobbles. The slope of the beach is a rather steep 13° . These conditions result in rapid erosion of the bluff toe.

The topographic profile has an almost vertical 3 foot toe, followed by a long lower slope with an angle of inclination between 32° and 35° . A major break in

slope occurs 74 feet above the beach at point B in the diagram. Above point B the slope is 26° . This configuration gives a total bluff height of 117 feet.

The stratigraphy at this location is as follows. At the base and buried by slump debris in most places is at least 10 feet of silty pebble cobbly till. Above the till, slumped material covers the slope to a height of about 18 feet. Exposed above the slump debris is a layer of interbedded fine sand and silty 18 feet thick and a 4 foot thick layer of medium sand. Over the sand is about 6 feet of silt and 35 feet of red brown silty till. This exposure varies from those in section 28 in that the gray cobble pebble till appears thicker and the upper red brown till is thinner. Seeps are located in the medium sand unit at the medium sand and interbedded fine sand and silt contact. In this stretch north of profile 1 at 22.2 a stratigraphic column has 24 feet of the silty pebble cobble till at the base. These conditions extend north to 22.31.

At 22.31 and extending north to 22.4 the bluff is in an almost stable condition. In this area the beach is greater than 25 feet wide and the slope is not failing at this time, however due to its steep slope and closeness to those areas which are eroding it appears to be only a matter of time before this area is also affected.

North of this stable area is another area of slope failure. From 22.41 north to 22.45 the slope is subject to translational slides.

North of this area the beach widens to greater than 20 feet and in places up to 70 feet. This protects the toe of the bluff which allows the upper slopes to maintain a stable configuration. The entire area from 22.46 north to 22.75 is considered relatively stable.

North of the stable area at 22.75 the bluff is subject to slumping and sliding despite the fact that the beach is 70 feet wide. These conditions exist to 22.88. It is through this zone that profile 2 was measured.

In profile 2 (22.78) the bluff height is 93 feet. The topograph profile has the familiar shape of a slump type failure, but without the vertical wave cut toe (the lack of toe erosion is due to the wide beach). Above the mound of debris at the base of the bluff is a long even slope (from A to B on the drawing).

The first in-place visible stratigraphy in profile 2 is a sand layer exposed about 22 feet above the beach. Over the sand is an undetermined amount of silt and at least 55 feet of red brown silty till. The failure seems to have been triggered by ground water seepage in the sand layer, below the silt and red brown till. The break in slope at B corresponds to the seat of the failure and the change in stratigraphy.

North of profile 2 from 22.88 to the end of the section the bluff is relatively stable. The beach is very wide (73') and the bluff is highly vegetated.

The erosion in this area is not on the bluff but instead behind the bluff in a very deeply cut ravine. At the mouth of the stream which cut the ravine is a sand terrace either from the stream drainage or built by an old higher lake level. (location 22.93)

Beyond the stream channel at 22.97 there is a number of huge conglomerate boulders resting on the beach. These boulders are evidence of an unexposed gravel layer in the bluff at this location. The cementing matrix of the conglomerate is highly silicious.

The section ends in an area of relative stability.

Section 14/15, T. 11 N.

Section 14/15 is the central section of reach 15. Best access to the bluffs and beaches is through the use of two dirt roads branching from U.S. 32, both of which lead directly to the beach. Land use in section 14/15 is primarily farming with several residences located near the shore.

The coast of this section, due to its N 32° E, is much longer than 1 mile.

(3,200 feet of shore in section 15 and 3,500 feet of shore in section 14). For purposes of description using the presence or absence of a bluff, the stretch is best divided into 3 parts. The southern most part is 2,500 feet long, the central part is also 2,500 feet long, and the northern part is about 1,700 feet long.

The southern part of section 14/15 is characterized by a bluff 60 feet to 90 feet high and having a slope between 32° and 37° .

At the southern section line and extending to 15.06 there is a 40 foot wide sand beach. Profile 1 was measured on the bluff above this stretch of beach at 15.03. The slope at this point is characteristic of the southern 1/2 of the southern 2,500 feet section. The bluff height is 88 feet and the vegetative covering is about 75% to 85%. The upper 1/3 of the bluff has a slope of 36° and the lower 2/3 has a slope of 32° . The bluff is subject to many shallow translational slides and some flowage. No stratigraphy was visible because of veneer of red brown silty till. The toe of the bluff is formed from slides debris of the same till. These slope conditions are present from 15.0 to 15.18 where a large ravine dissects the bluff. The beach however changes in composition from the wide sand type to a 25' pebbles and cobbles beach which is evidence of a higher energy, erosion producing zone.

North of the ravine from 15.18 to about 15.28 the bluff is slightly lower and more stable. The beach in this stretch is 5' to 20' wide and has a very coarse composition of pebbles and cobbles. Profile 2 is an example of these conditions.

In profile 2 the bluff is about 62 feet high and has a constant slope of 34° . The vegetative cover is 100% comprised of trees (10 in. diam.) and miscellaneous undergrowth. The vegetation and soil produced by it prohibited the recording of any stratigraphy. However active seeps were observed about 18 feet above the beach and can be attributed to a sand and gravel layer known to be present. The beach at this point is 23' wide (pebbles and cobbles).

From 15.28 to 15.35 the conditions are similar with respect to bluff height, slope angle, beach width and beach composition however the slope is slightly less stable and several translational slides scar the bluff surface.

In the central part of section 14/15 north of 15.35, drastically different slope conditions exist. From 15.35 to 15.4 a small terrace lies at the mouth of a creek. From 15.4 to 14.53 there is no true bluff - only a gentle rise from the beach to the fields beyond. At 14.53 another stretch of terrace extends to 14.8.

The terrace itself is made completely of very clean buff colored medium sand. Several residences are located on the terrace and three structures constructed by the property owners protect the easily eroded sand in front of their homes. These structures are (1) at 15.36 a stone revetment; (2) at 15.38 a concrete seawall, and (3) at 14.6 another stone revetment. On the terrace at 14.7 a small pond is formed just above lake level by the damming action of the beach deposits. The stream which feeds the pond continues toward the north just above lake level. At its widest point the terrace is about 400 feet wide. (14.77).

The beach conditions in the area in front of the terrace are as follows. From 15.4 to 15.5 the beach is 5 to 15 feet wide and made of cobbles and boulders. From 15.5 to 14.6 the beach is about 15' wide and composed primarily of sand, and from 14.6 to 14.8 the beach is 5 to 20 feet wide and has a composition of pebbles and cobbles.

The northern most of the three parts into which section 14/15 is divided is characterized by a low bluff such as that found in profile 3. The low bluff zone starts at 14.8 at the terrace level and extends, rising to the north to the end of the section. At the profile 3 location (14.92) the bluff is 52 feet high and has a slope of 36° . The bluff is about 95% vegetated by juniper and miscellaneous weeds and is subject to small shallow translational slides. The

stratigraphy is difficult to determine but it is thought to include 10 feet of sand, overlain by several feet of red silt and finally about 38 feet of red brown silty pebbly till. The beach below the bluff is 5 to 20 feet wide and is made of cobbles and pebbles. These conditions continue until just before the end of the section where the bluff becomes more heavily vegetated by small trees.

Section 11, T. 11 N.

The shoreline of section 11 in reach 15 is a zone of marginally stable high bluffs (70 to 90 feet). Other than 7 homes on the bluff top in the middle of the section the land is used for farming. Best access to the beach and bluff is by way of two dirt roads stemming from U.S. 32 or by Lake road at the northern section line. For purposes of discussion section 11 is broken into five parts.

The southern most part of section 11 is an area of relatively stable bluffs. This area extends from 11.0 to 11.1 and has a length of about 600 feet. In profile 1 which is characteristic of this part of section 11 the bluff is 70 feet high and has a topographic profile with 3 different slopes. The lower slope is 31° , the middle of the bluff has an angle of 43° and the upper slope angle is 31° . The entire bluff is wooded and covered with undergrowth. The vegetation prohibited the recording of any stratigraphy, however seeps located 30 feet above the toe indicate the position of a sand layer thought to be present. The beach beneath the bluff in this area is 5' to 15' wide and has a composition of pebbles and cobbles. The coarseness of the beach demonstrates the erosion producing conditions present, and as the bluff is very steep, has seeps, and probably sand near the foot this is a prime location for rapid erosion in the near future.

The second of the 5 parts into which section 11 was divided illustrates the stage of bluff erosion which follows from the conditions just discussed. In this area from 11.1 to 11.30 the bluff is subject to major slides. Profile 2 is typical of this stretch of the bluff. At the profile 2 location (11.12) the

bluff height is 71 feet and the slope angle averages 39° . At the base of the bluff is a large block of slide debris which indicates that the slide was very recent (because elsewhere in this area of sliding the debris mound has been removed by wave action). The vegetative cover is only 20% on the main slope but a veneer of red brown silty till obscures all stratigraphy except for a layer of sand 20 feet above the top. In the sand layer seeps are located which support numerous horsetails. The beach along this stretch of shore is a constant 5 to 20 feet wide and has a texture of pebbles and cobbles.

The third part of section 11 extending from 11.3 to 11.54 is a stretch of stable bluff with a narrow terrace giving good toe protection. The bluff height in this stretch increases from about 70 feet to about 85 as one moves north. The terrace width is about 60 feet for most of its length and has a very clean buff medium sand composition. The beach at the southern and northern end of the terrace is 5' to 15 feet wide and is made of pebbles and cobbles, near the middle of the terrace the beach width increases slightly to about 20 feet while retaining its pebble-cobble texture. The stretch of bluff should remain stable until all of the terrace has been removed.

The fourth part of section 11 is very similar to the second. Again the bluff is subject to translational slides (from 11.54 to 11.84) and the beach is a narrow 5 feet to 15 feet. Profile 3, drawn at 11.6 is typical to this part of the shore. The topographic profile has one major break in slope. The lower slope is inclined at 42° and has a vegetative cover of 0%. This allows a good look at the stratigraphy present. The toe is covered by slide debris but immediately above the debris a gray and red massive silt with some pebbles is located. Over this layer about 10 feet above the beach is a unit of very coarse pebbles, cobbles, and boulders. The pebbles at this layer are very angular and the entire unit is partially cemented by silicious material. This gravel boulder layer is about 27 feet thick. At the top of this layer 38 feet above the beach a break in slope corresponds to the change in stratigraphy.

The upper slope with an inclination of 34° is formed by 4 feet silt with fine sand lenses (sitting on top of the gravel boulder layer) and 25 feet of red brown pebbly silty till over the silt. The vegetative cover on the upper slope is about 90% and obscures the stratigraphy except in drainage channels.

The beach in this part of section 11 is formed from cobbles and pebbles and is 5 to 15 feet wide.

The fifth or northern most part of section 11 is very similar to the first. From 11.84 to the end of the section the bluff is on the border of stability. The slope is steep (30°) and the vegetative cover (for what its worth) is 100% (small trees and weeds). The stratigraphy, though limited, exposes a sand layer low in the bluff. These conditions make this area very susceptible to future erosion (already 2 small slides scar the slope). The only factor prohibiting immediate erosion is the presence of a 20' to 30 foot wide pebble cobble beach. Without this minimal toe protection this would probably be a major slide area.

Profile 4 (11.98) is characteristic of the northern end of section 11. Here the bluff height is 75 feet (slightly less than profile 3) and the slope angle is 30° . The lower sand unit is located 16 feet above the beach and vegetative cover is 100%. A 32 foot pebble cobble beach protects the toe. Immediately north of this profile in sec. 3/1 a sand terrace protects the bluff.

Section 2/1, T. 11 N., Reach 15

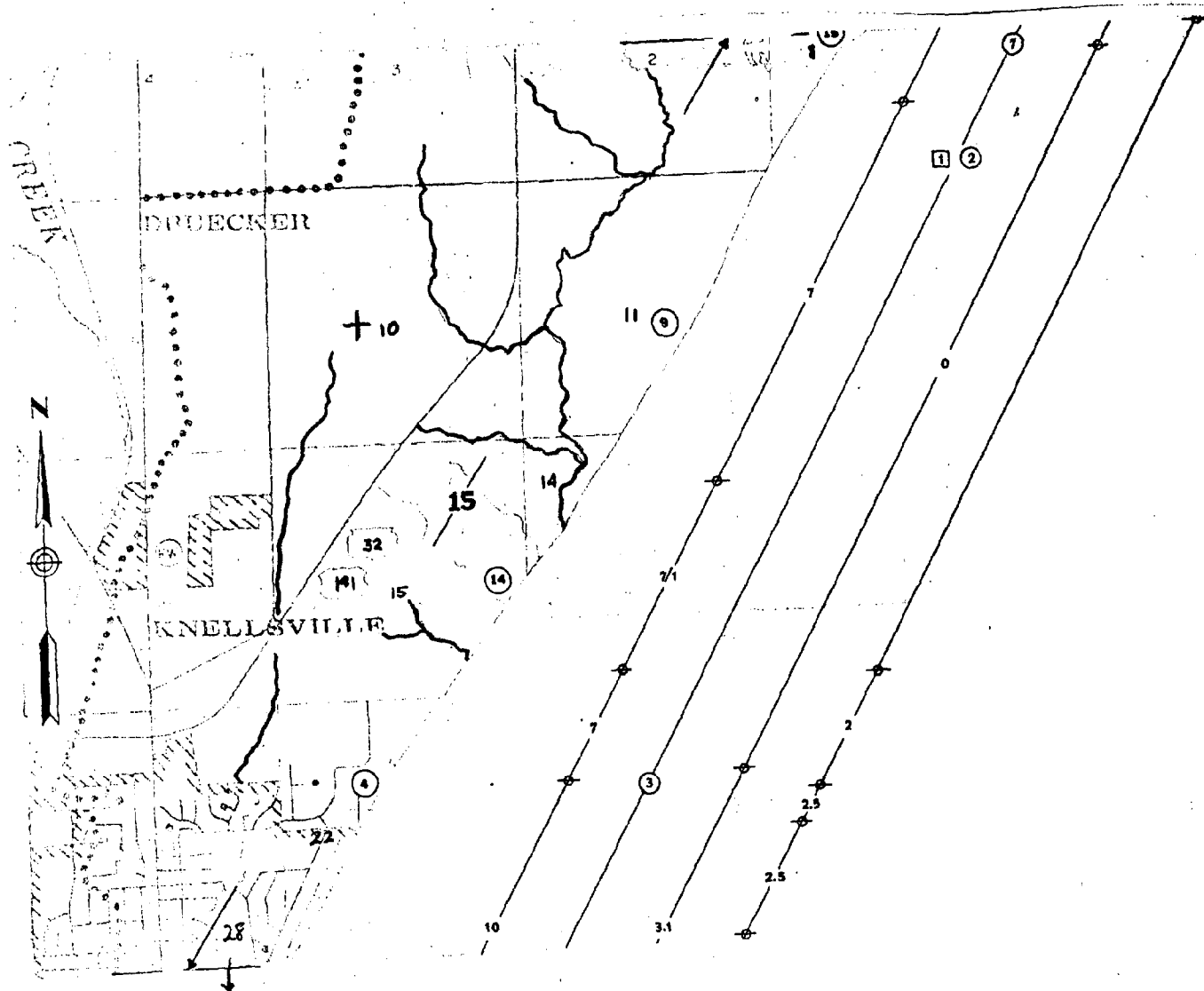
The southern 1/2 of section 2/1 is the northern most stretch of reach 15. Best access to the southern 1/2 of the section is by way of Lake Road which dead ends at the bluff on the southern section line. Land use of the southern 1/2 of section 2/1 is for farming.

The slope, beach, and toe material conditions are very uniform throughout section 2/1. In the southern 1/10 of the section the conditions are exemplified by Profile 1. At this point (2.0) the bluff is 75 feet high and in a stable configuration. The slope angle is 30° and the bluff is completely vegetated by small trees and weeds. There is no evidence of failure despite the presence

of an 8 foot thick sand layer just above the toe. The 32 foot cobble and pebble beach is probably responsible for the lack of toe erosion.

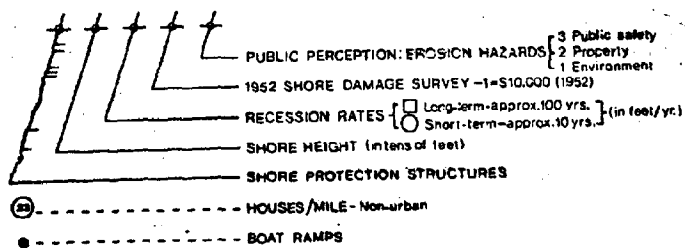
From profile 1 (2.0) north to profile 2 (1.16) the slope conditions are the same. The angle is 30° and the bluff is completely vegetated. The height of the bluff decreases slightly over this distance, being only 65 feet at profile 2 (1.16). At profile 2 the pebble cobble beach is 18 feet wide having narrowed slightly at 1.1. However, the more narrow beach does not affect slope stability because of the presence of a 76' wide sand terrace. The terrace, thought to be of Nipissing age by Alden, continues northward from 1.1 into Sheboygan County. The excellent toe protection allows a stable and or gentle slope to be maintained throughout the northern $6\frac{1}{2}$ miles of Ozaukee County.

The terrace remains about 70 to 100 feet wide and the pebble and cobble beach remains 5 to 20 feet wide north to 1.45 where dolomite bedrock outcrops at lake level. In this area (from 1.46 to 1.58) angular dolomite cobbles and horizontal bedrock form the 15 foot beach. The bedrock forms a prominent point at 1.5 which marks the northern boundary of reach 15.



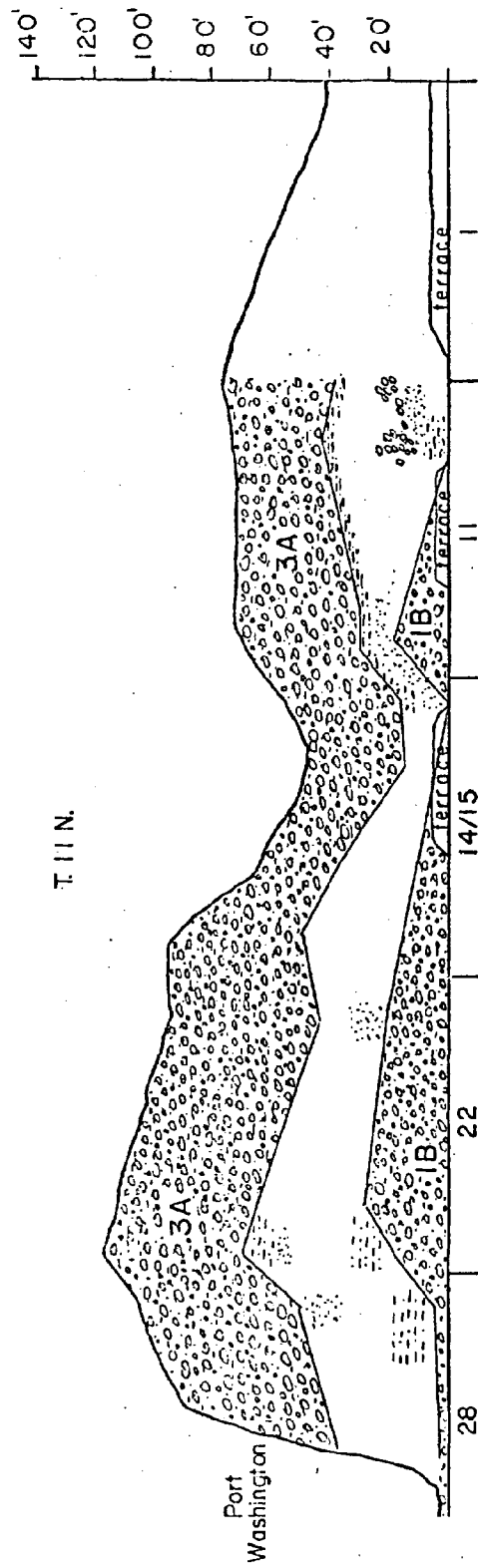
Reach 15

1 mile












Ozaukee Co.

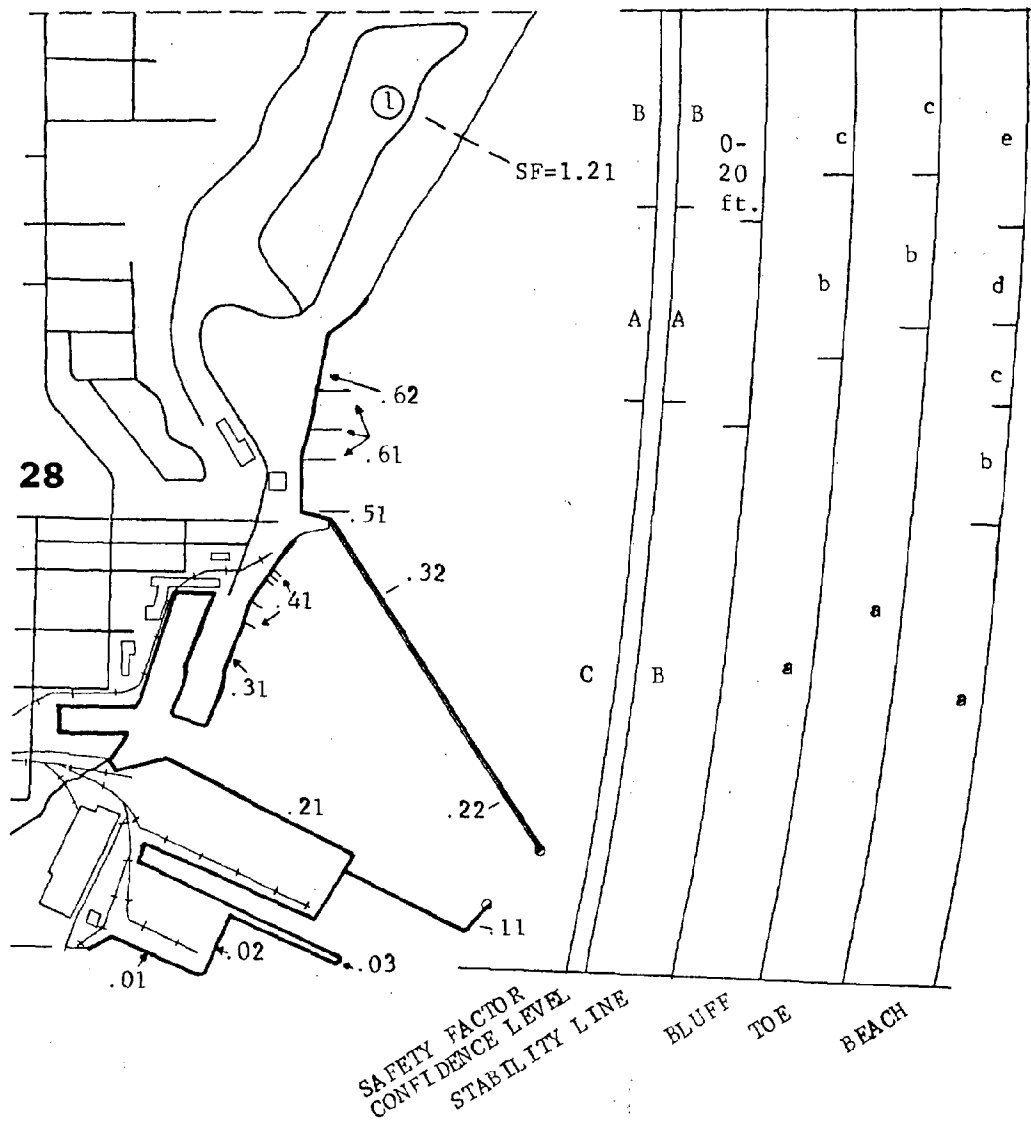
T. 11 N.



LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

Generalized longitudinal section showing bluff stratigraphy in Reach 15. Numbers along base of diagram are geographic (1 mile) sections.

SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
(stratigraphy visible)
- C-no stratigraphy
visible (low
confidence)

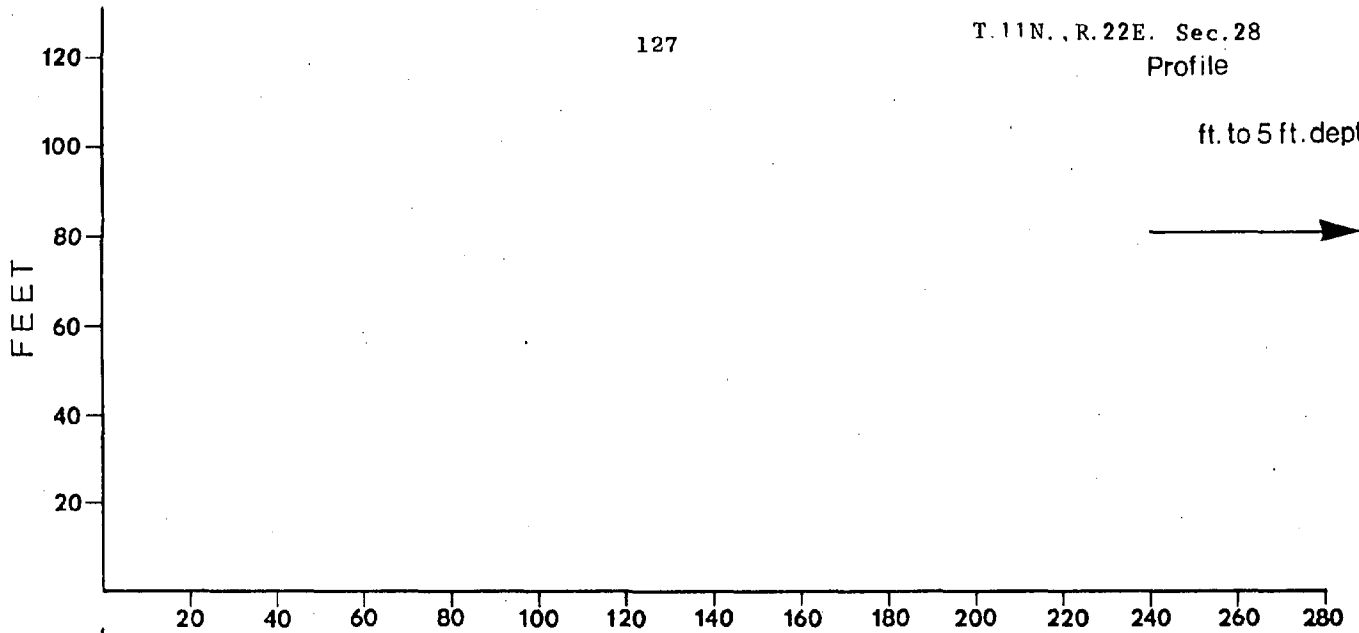
1. BLUFF	a-completely protected by jetty, sea-walls and revetment	b-very rapid erosion, very steep slumping planes and slides.	c-unstable, slumping and slides of a block torn from upper slopes	
2. TOE	a-slumped red-brown silty till	b-red-brown silty till slide debris and in place gray pebbly, cobbly till		
3. BEACH	a-no beach seawalls, jetty, revetment	b-sand, 15 ft. wide	c-revetment, (sewage treatment plant)	d-sand. 5 to 20 ft.
	e-cobbles 5 to 20 ft.			

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T. 11N., R. 22E. Sec. 28

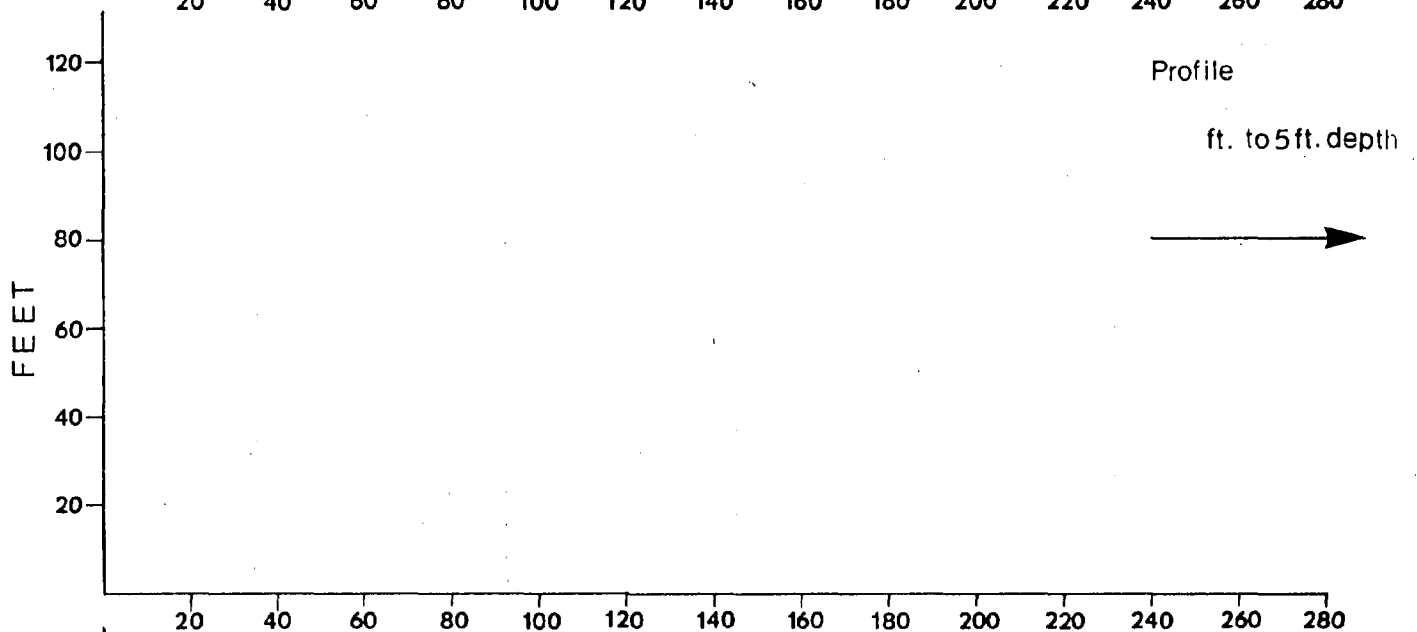
Profile

ft. to 5 ft. depth



Profile

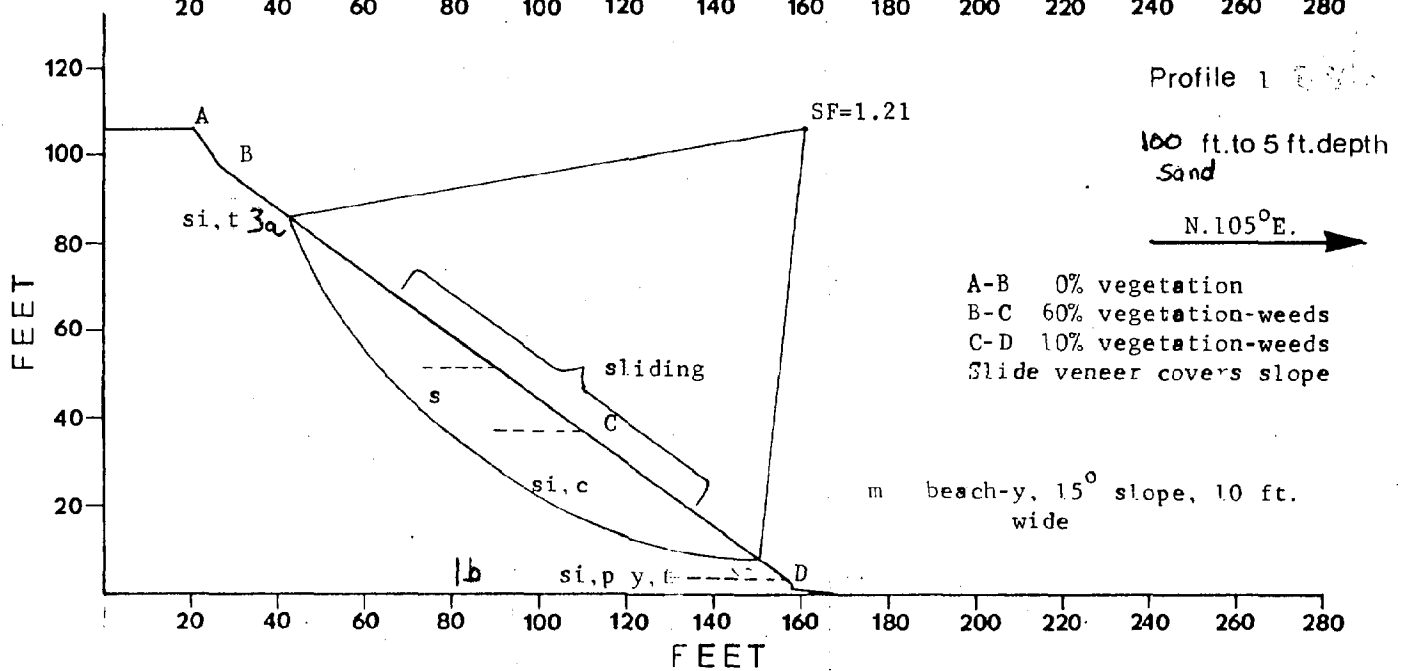
ft. to 5 ft. depth

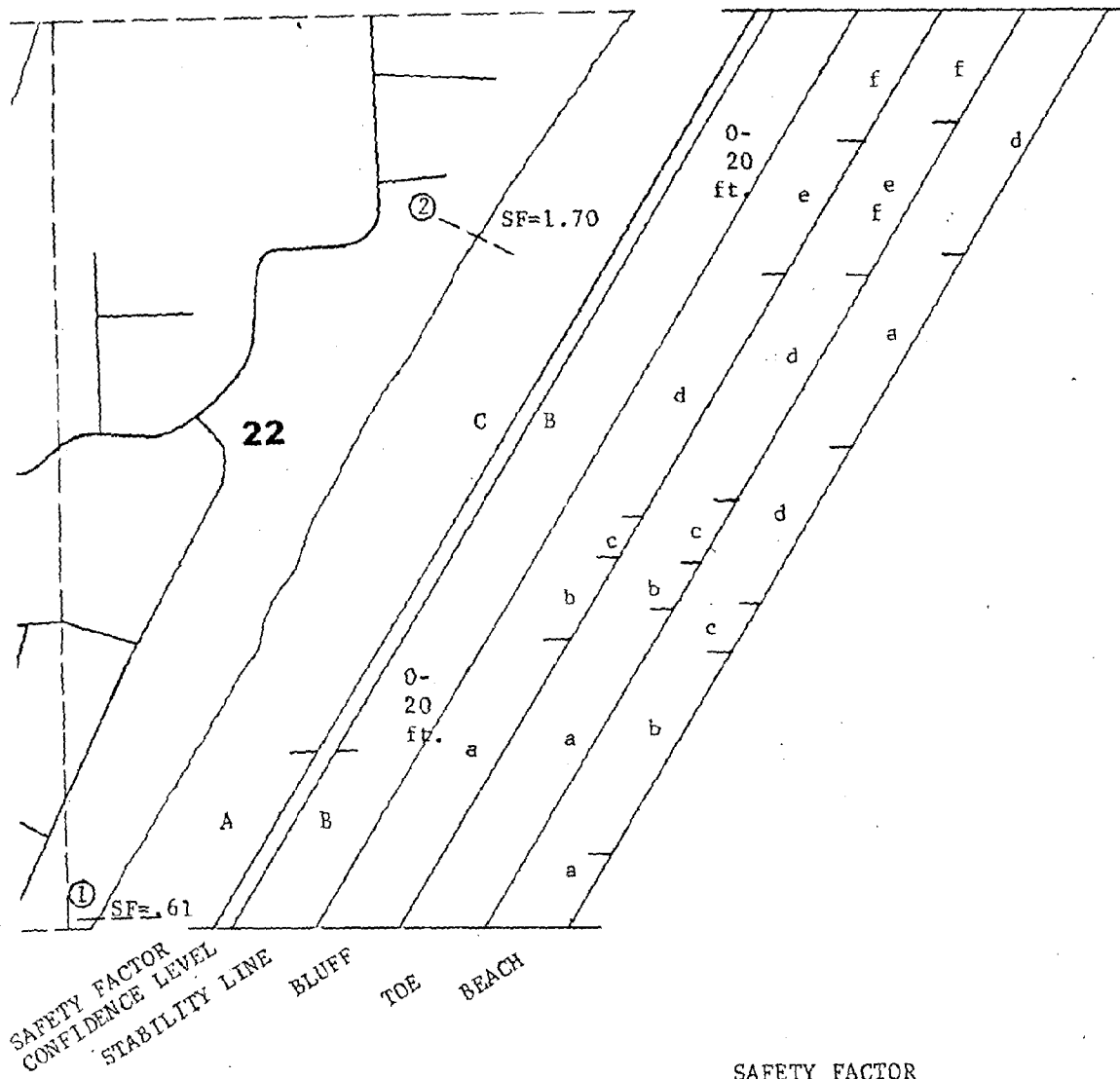


Profile 1

100 ft. to 5 ft. depth
Sand

N. 105° E.



SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

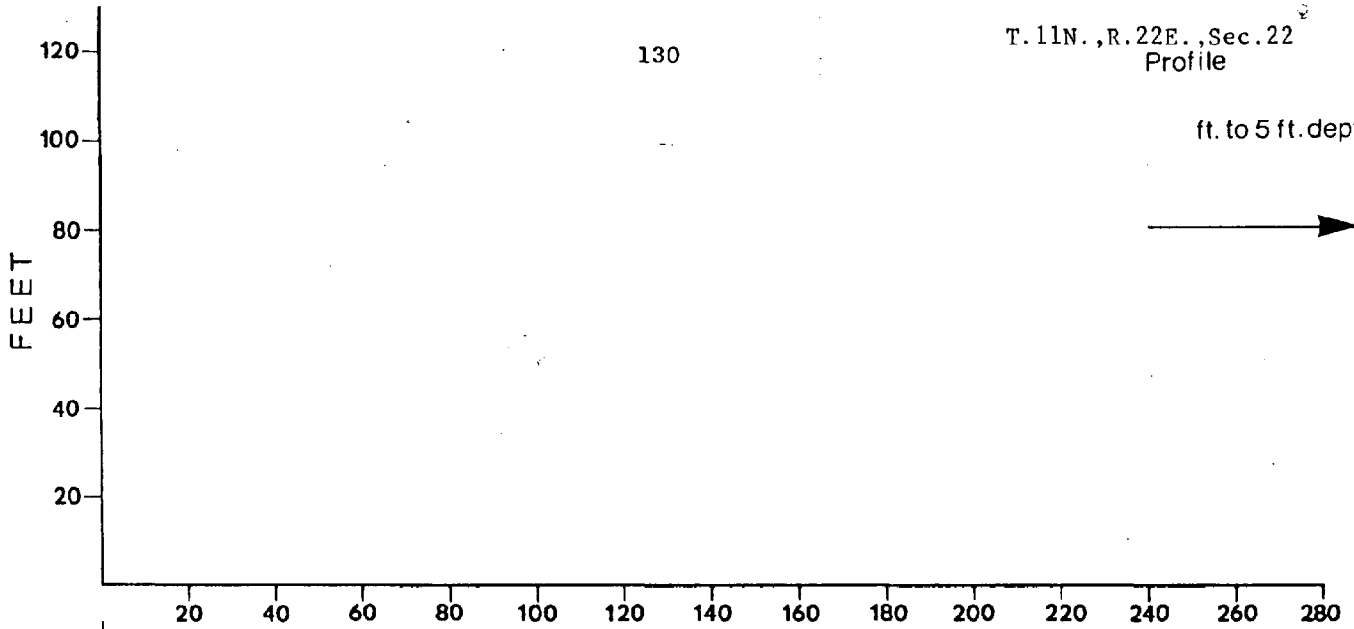
- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-shallow translational slides on lower slope slumping on upper slope	b-almost stable, subject to failure translational slides	c-several translational slides	d-relatively stable, no recent failures
	e-shallow translational slides	f-bluff almost stable, erosion caused by drainage system		
2. TOE	a-red-brown till slide debris	b-not visible	c-red-brown till slide debris	d-not visible, in places a sand terrace is found
	e-red-brown till slide debris	f-sand terrace over bluff toe		
3. BEACH	a-5 to 15 ft. cobbles	b-20 to 25 ft. sand	c-5 to 20 ft. sand and cobbles	d-very wide +30 ft. sand with gravel (pebbles) at water line
	e- +70 ft. sand with gravel (pebbles) at water line			
4. STRUCTURES- none in this section				

130

T. 11N., R. 22E., Sec. 22
Profile

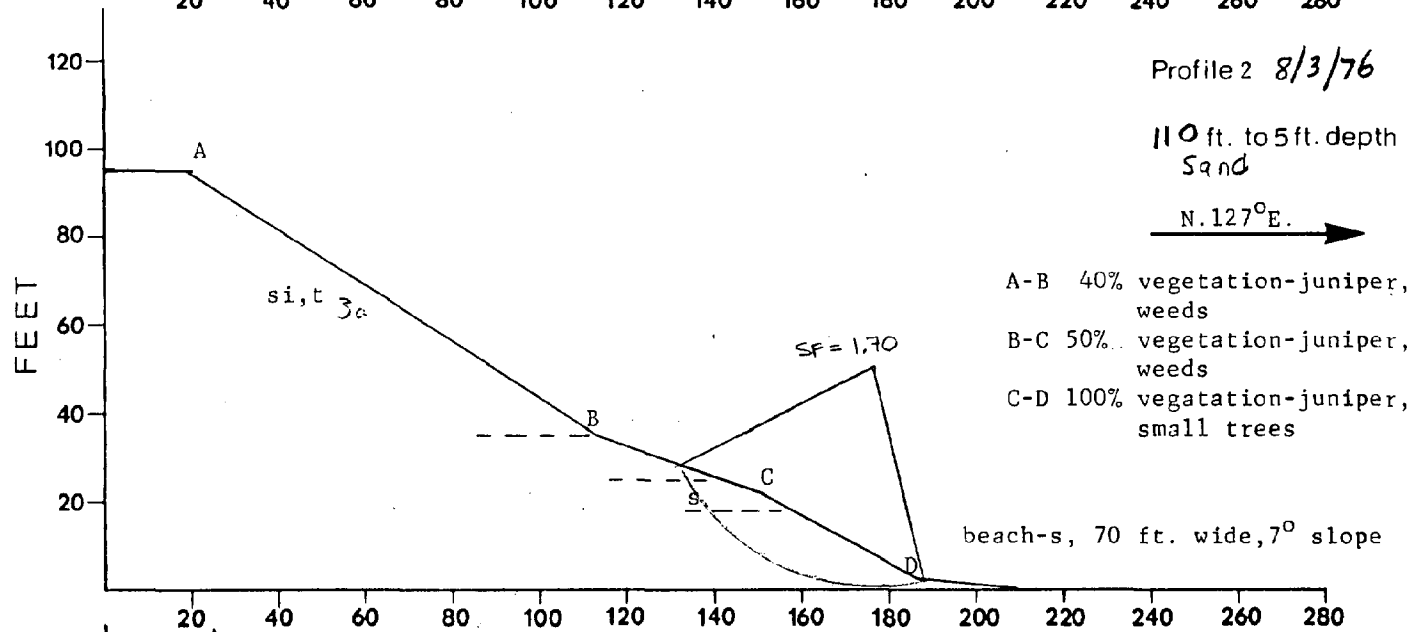
ft. to 5 ft. depth



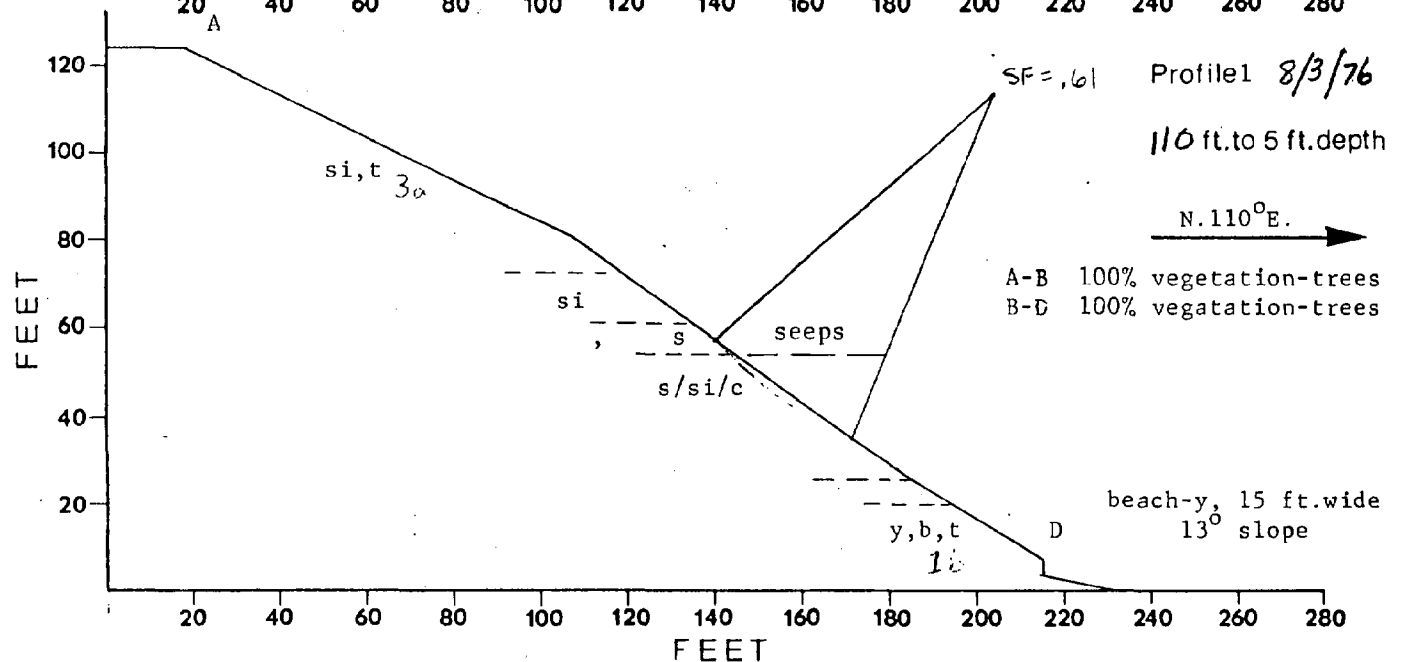
Profile 2 8/3/76

110 ft. to 5 ft. depth
Sand

N. 127° E.



- A-B 40% vegetation-juniper, weeds
- B-C 50% vegetation-juniper, weeds
- C-D 100% vegetation-juniper, small trees

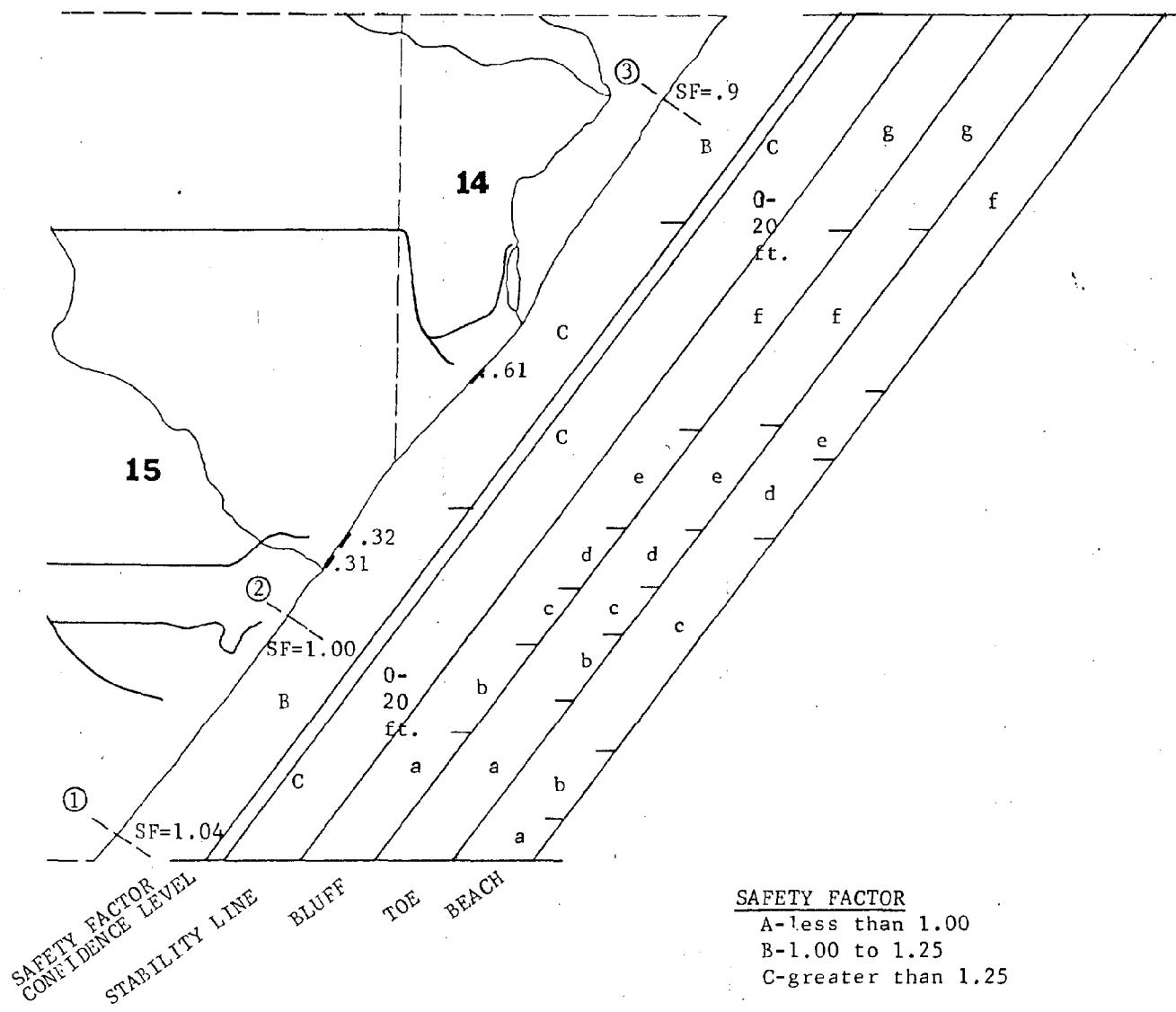


Profile 1 8/3/76

110 ft. to 5 ft. depth

N. 110° E.

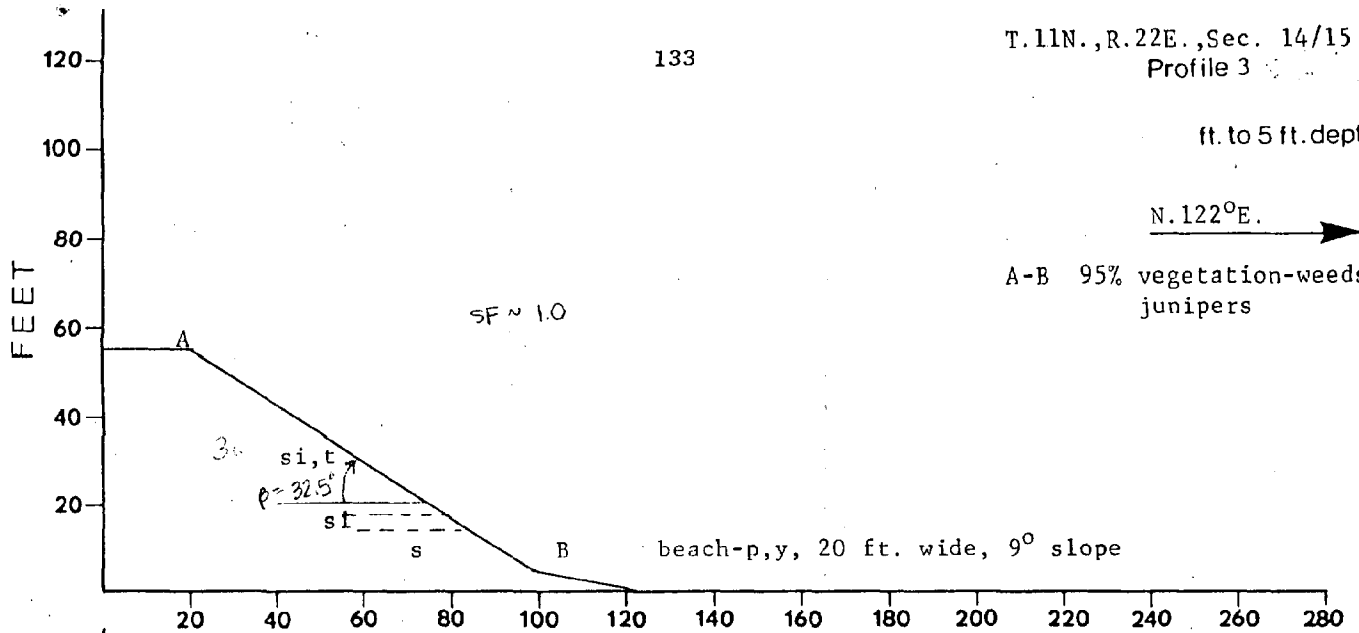
- A-B 100% vegetation-trees
- B-D 100% vegetation-trees



1. BLUFF	a-shallow translational slides	b-relatively stable, no recent failures. Steep slope and narrow beach make future stability doubtful.	c-shallow translational slides	d-small terrace
	e-no bluff or terrace, gentle rise	f-level sand terrace with gentle rise beyond	g-low bluff subject to translational slides	
2. TOE	a-red-brown till slide debris	b-not visible, most likely in place gray pebble, cobble till	c-red-brown till slide debris	d-sand terrace
	e-sandy silt in place	f-sand terrace	g-sand in place	
3. BEACH	a-less than 20 ft. sand	b-25 ft. cobbles and pebbles	c-5 to 20 ft. cobbles and pebbles	d-5 to 15 ft. cobble and pebbles
	e-15 ft. sand	f-5 to 20 ft. cobbles and pebbles		

ft. to 5 ft. depth

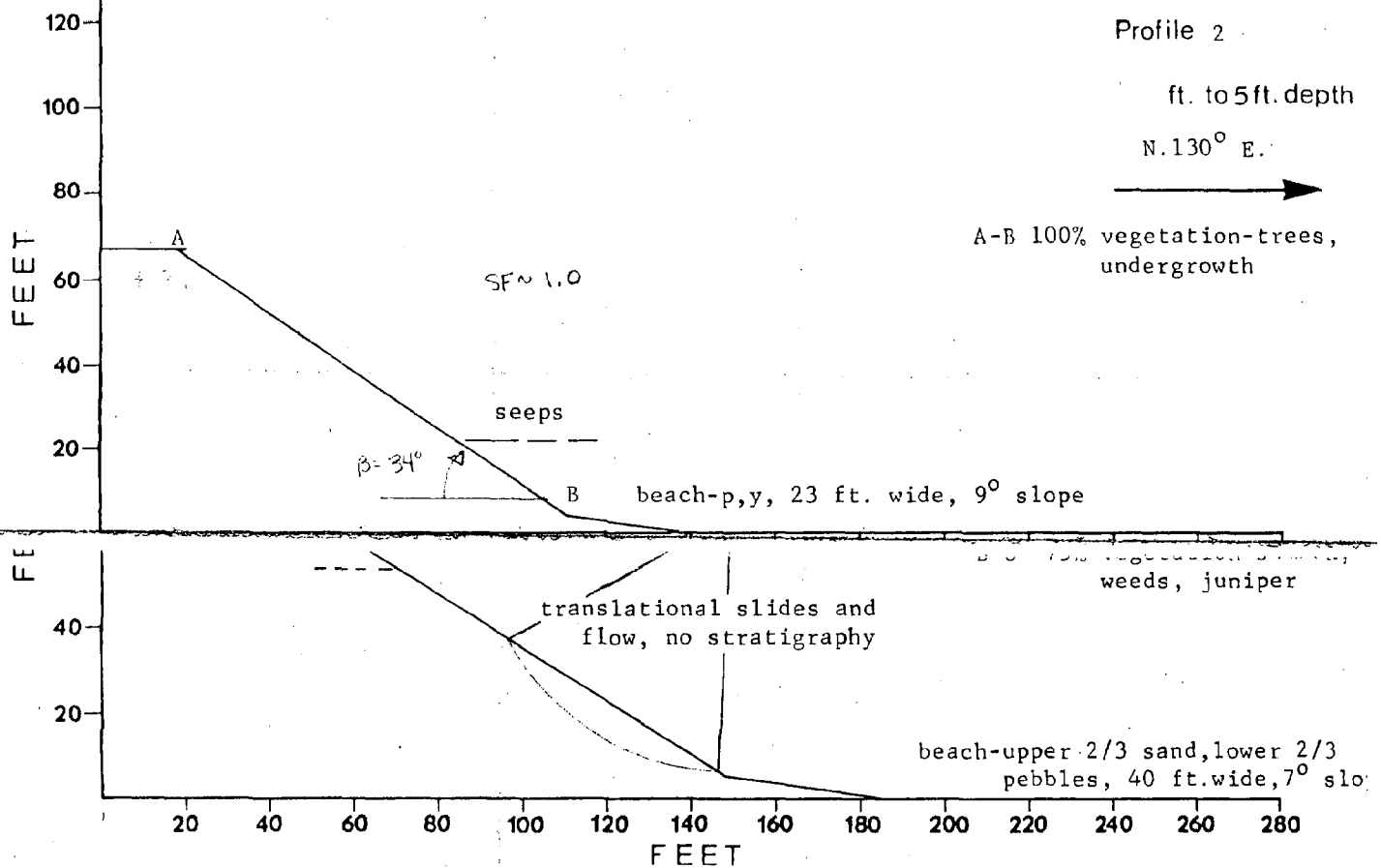
N. 122° E. →

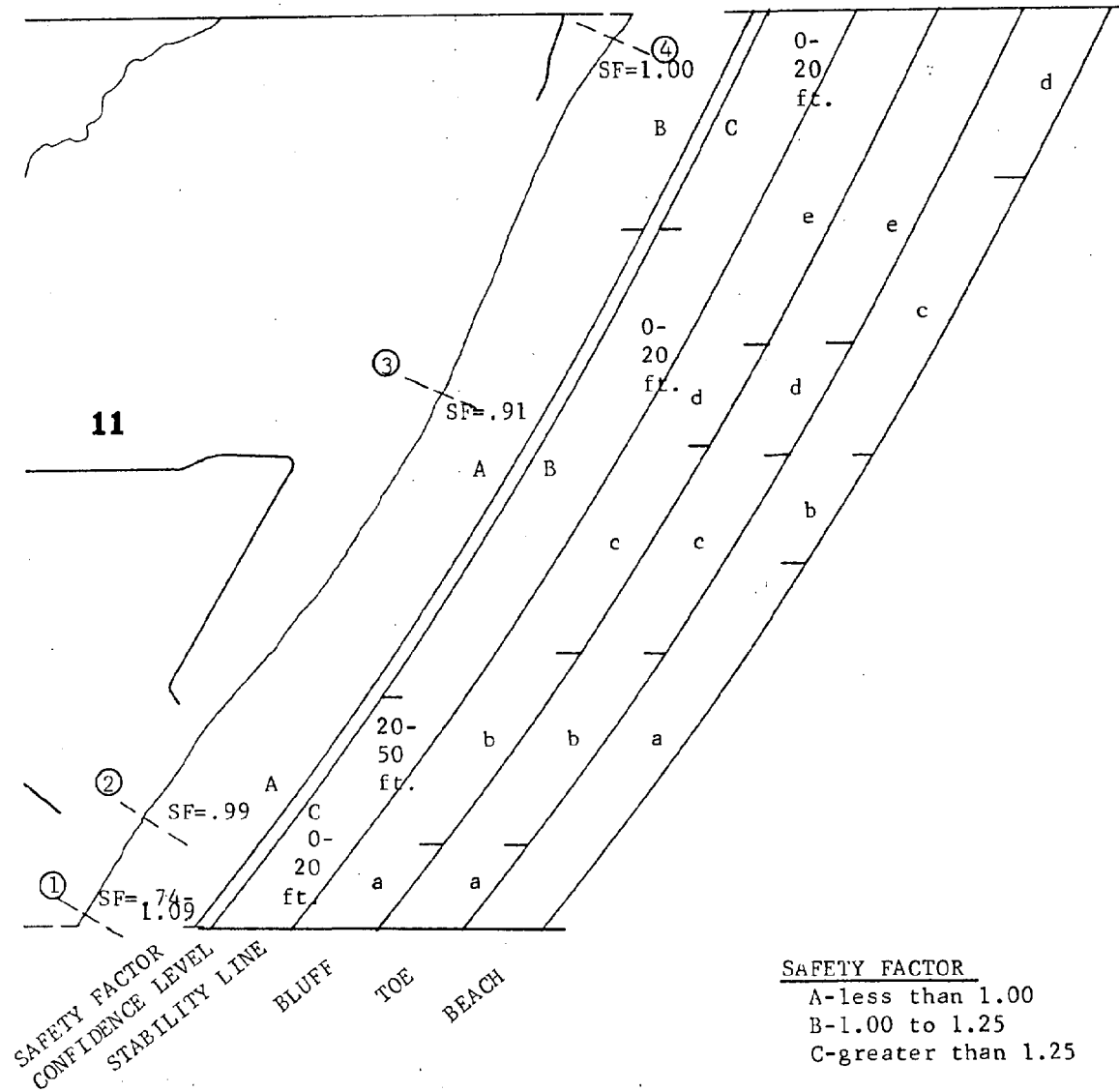
A-B 95% vegetation-weeds
junipers

Profile 2

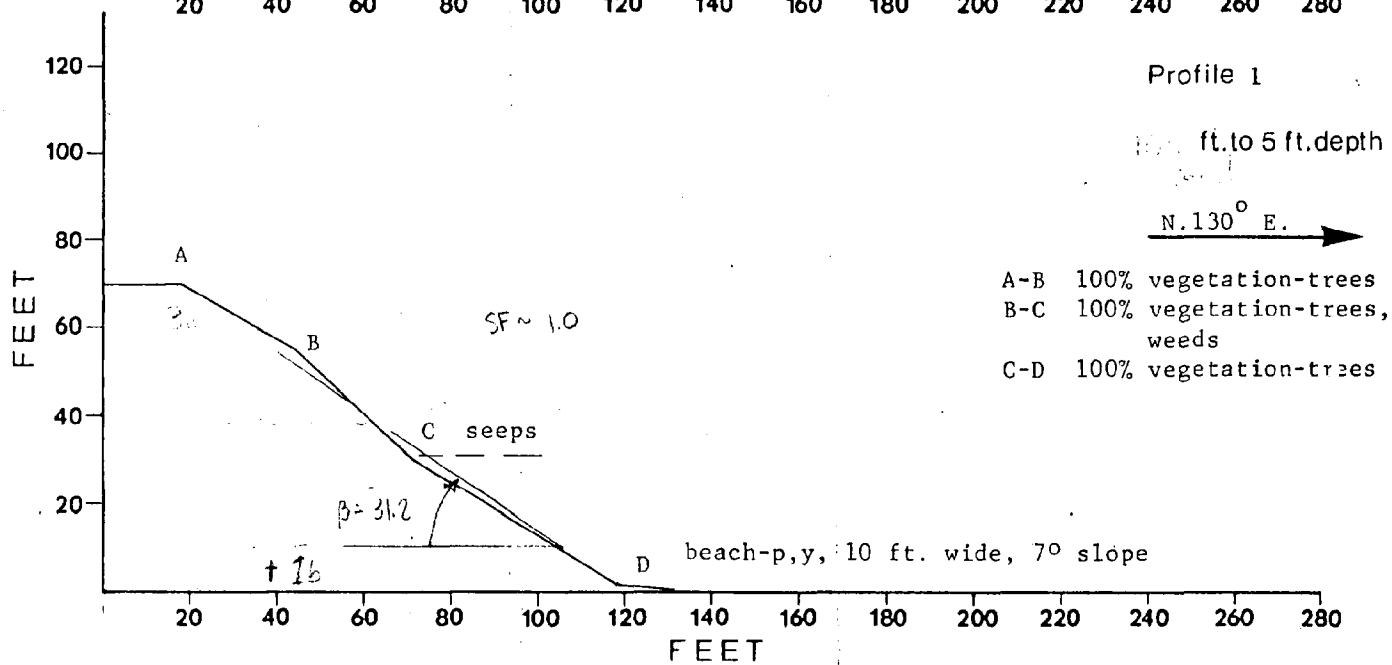
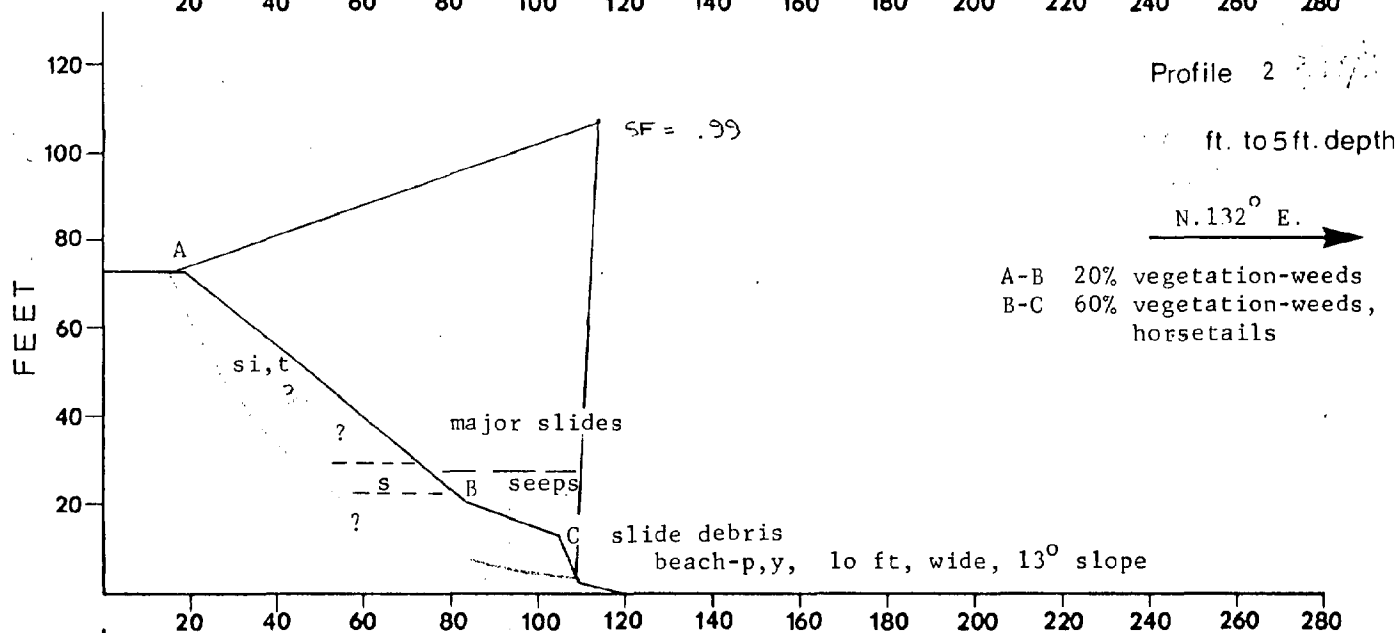
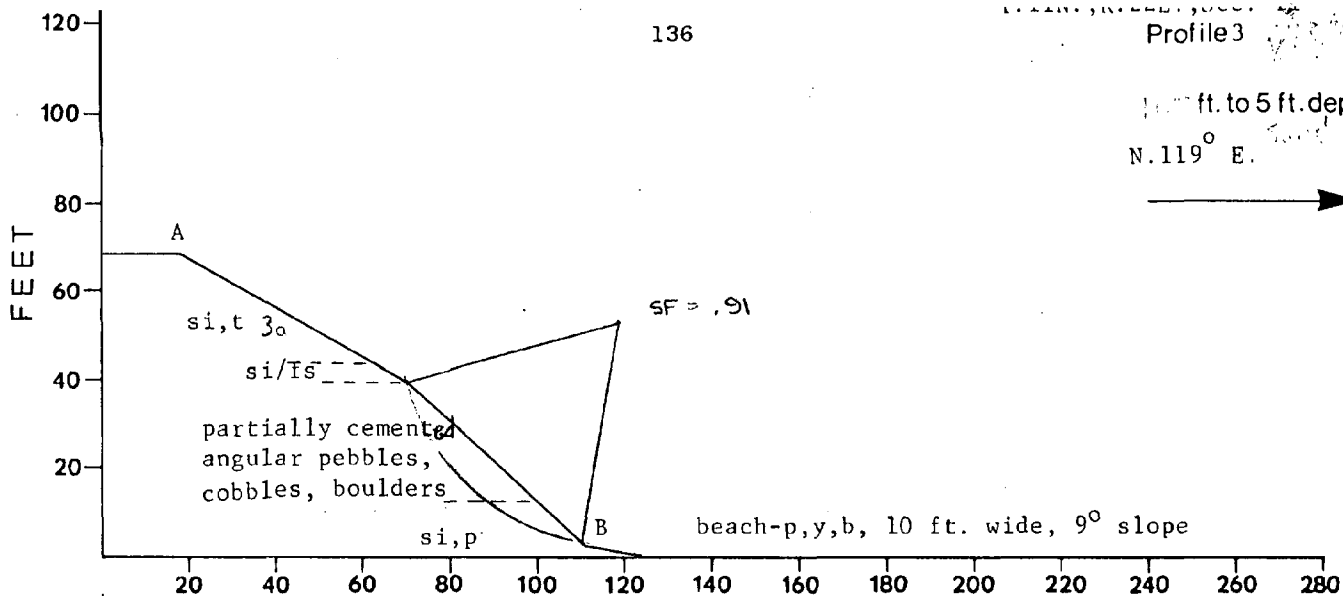
ft. to 5 ft. depth

N. 130° E. →

A-B 100% vegetation-trees,
undergrowth



1. BLUFF	a-relatively stable, no recent failures e-relatively stable, no recent failures, subject to rapid future toe erosion	b-shallow translational slides	c-terrace protects a relatively stable slope no recent failures	d-shallow translational slides
2. TOE	a-in place but unknown, sand most probable e-in place sand	b-red-brown till slide debris	c-small sand terrace	d-red-brown till slide debris
3. BEACH	a-5 to 15 ft. cobbles and pebbles	b-about 20 ft. pebble and cobble	c-5 to 15 ft. cobbles and pebbles	d-20 ft. widening to 30 ft. at end of section, pebbles and cobbles
4. STRUCTURES-none this section				

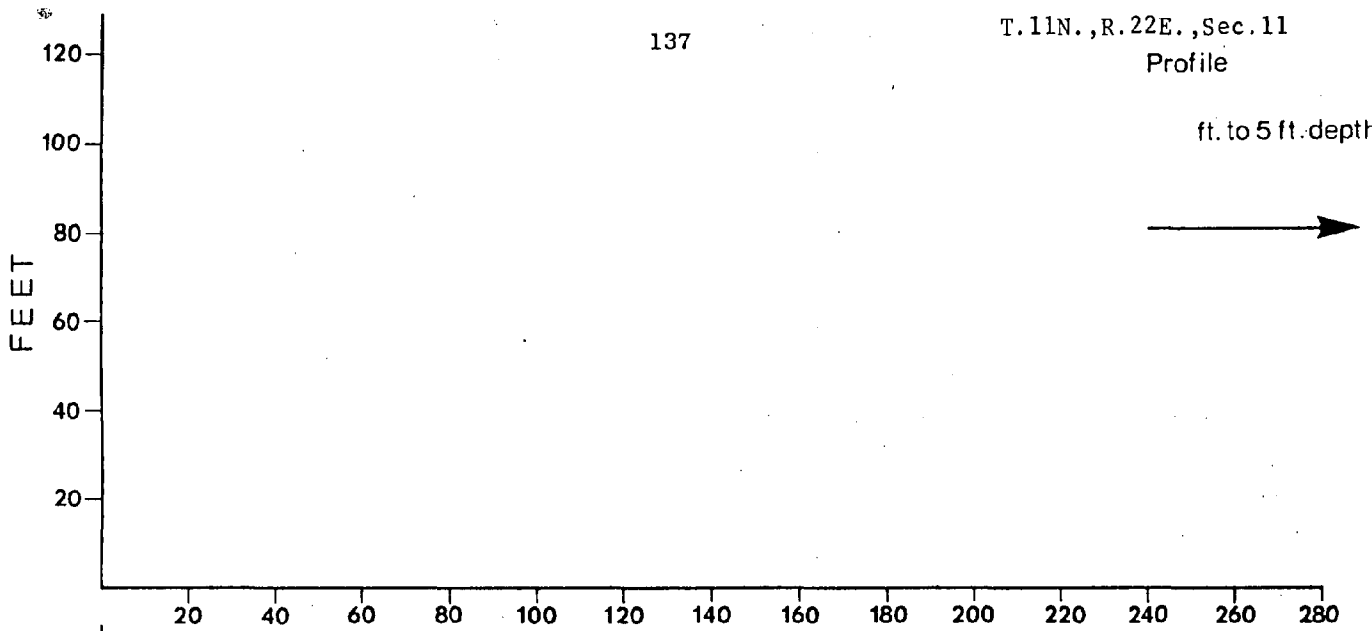


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T.11N., R.22E., Sec. 11

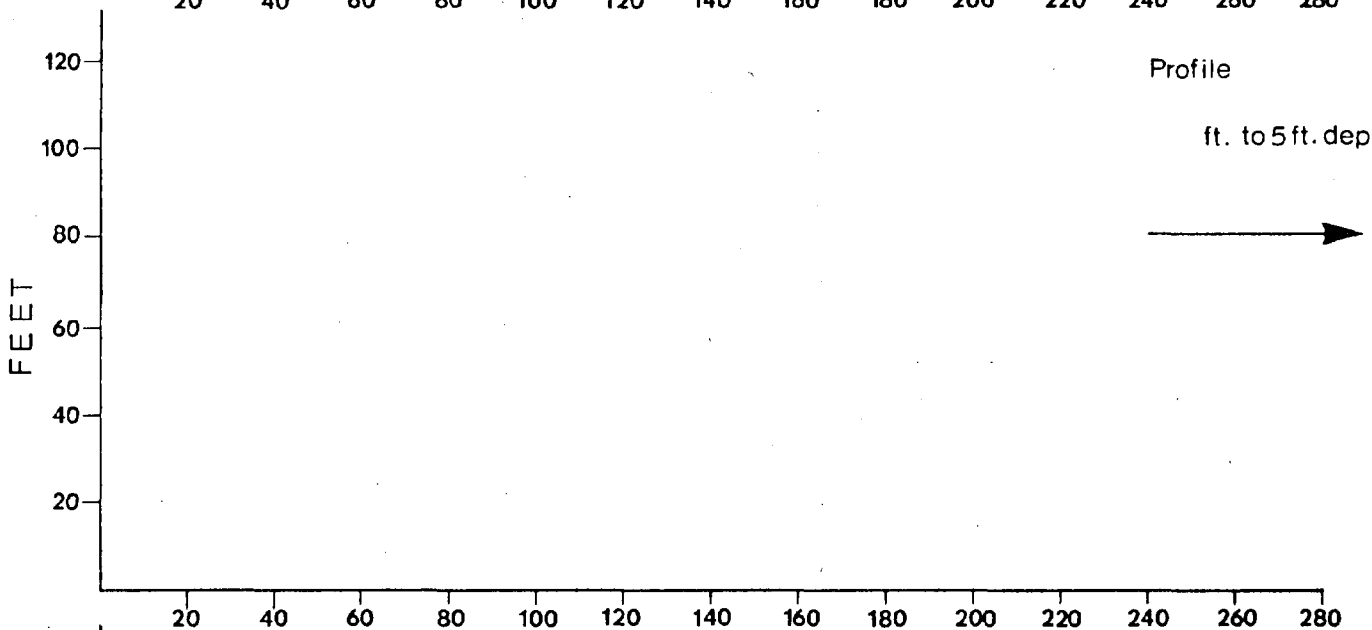
Profile

ft. to 5 ft. depth



Profile

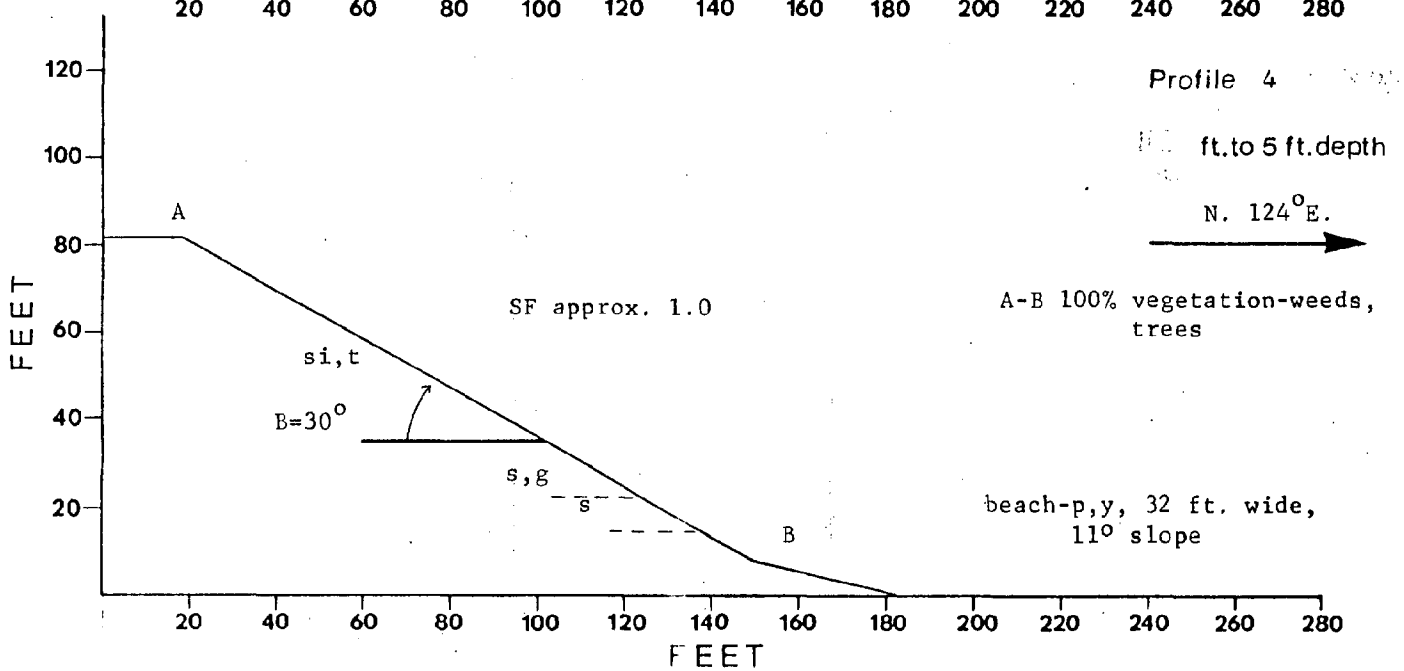
ft. to 5 ft. depth

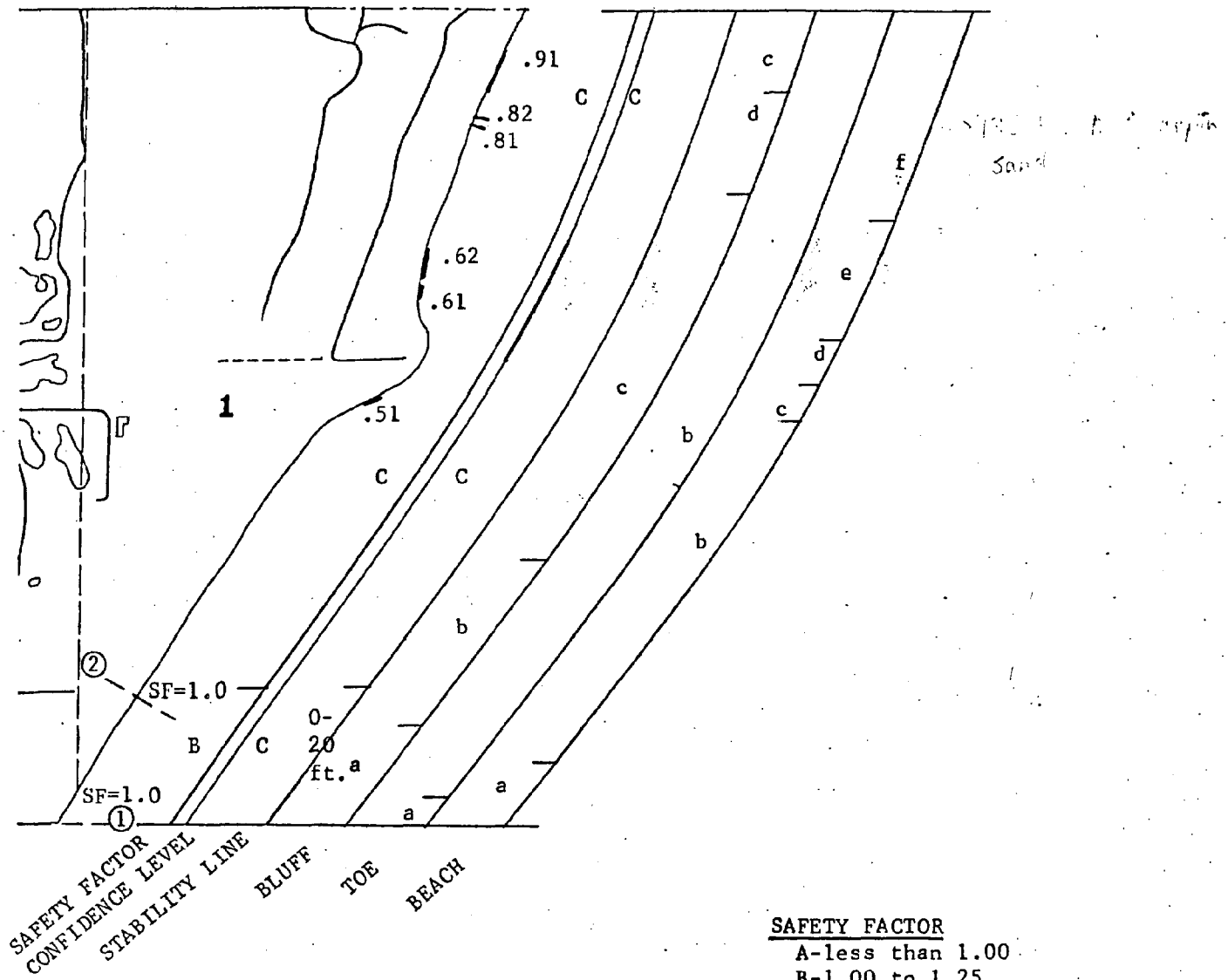


Profile 4

ft. to 5 ft. depth

N. 124° E.



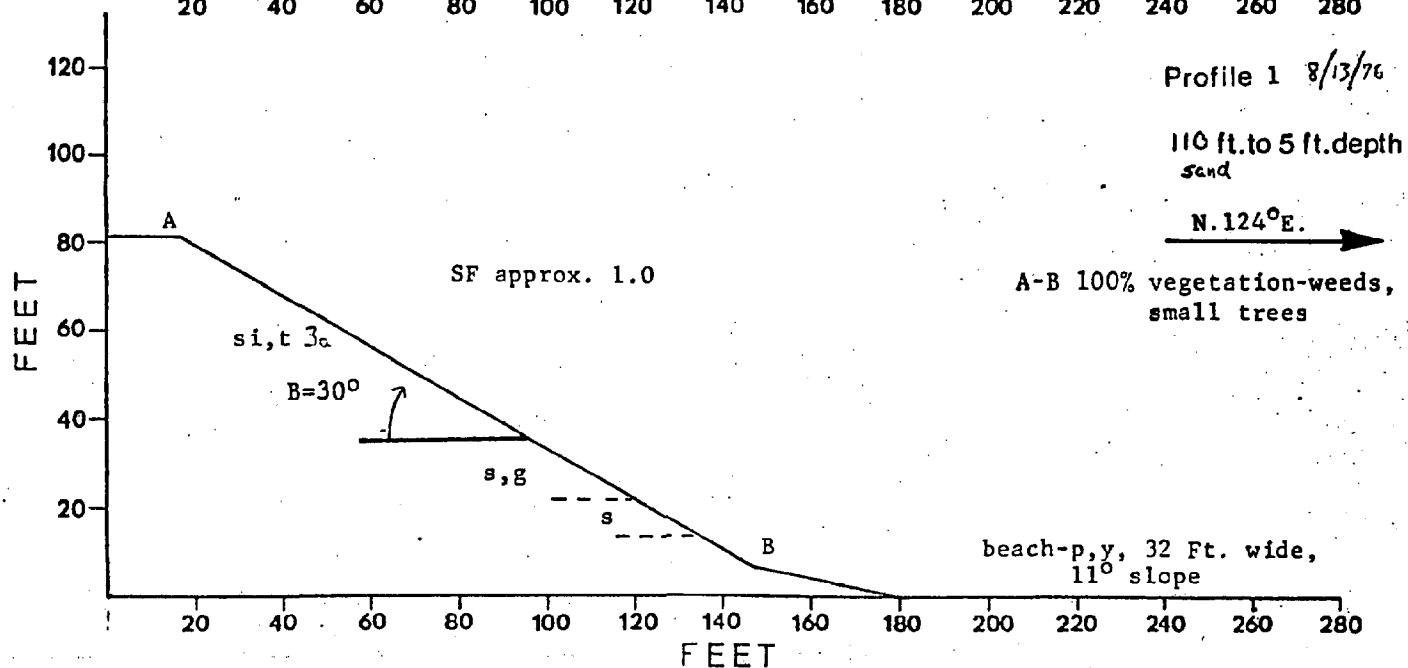
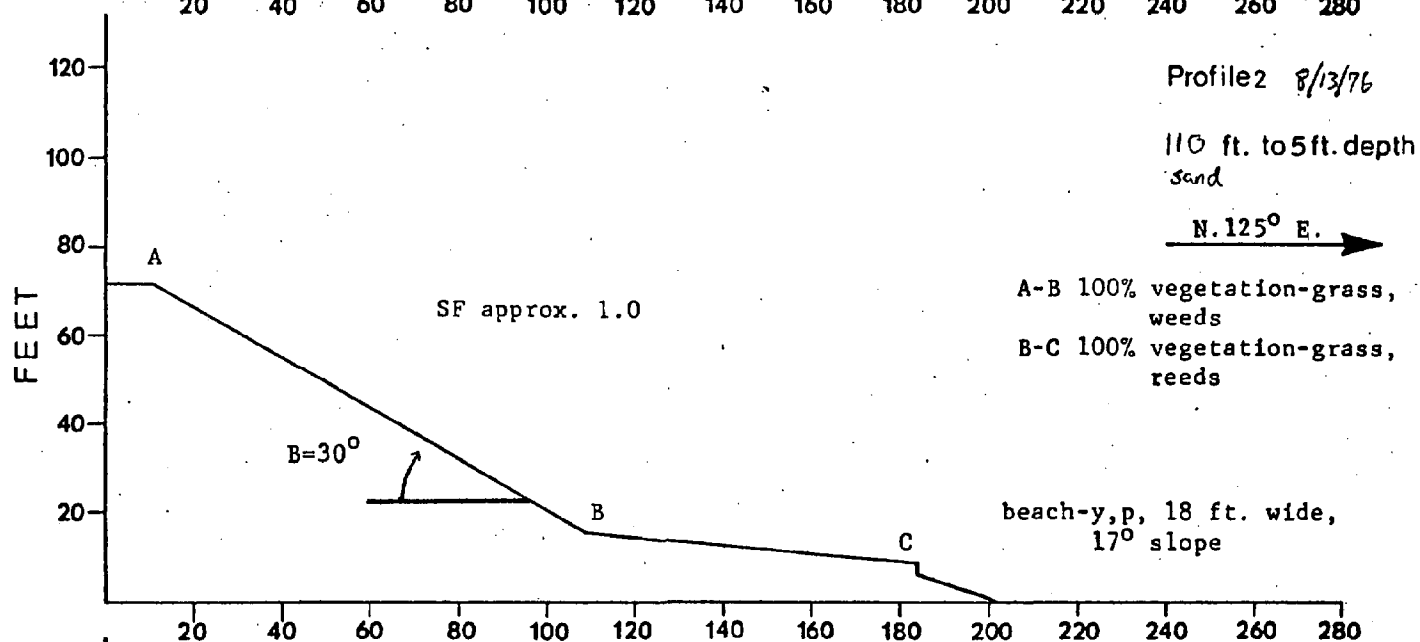
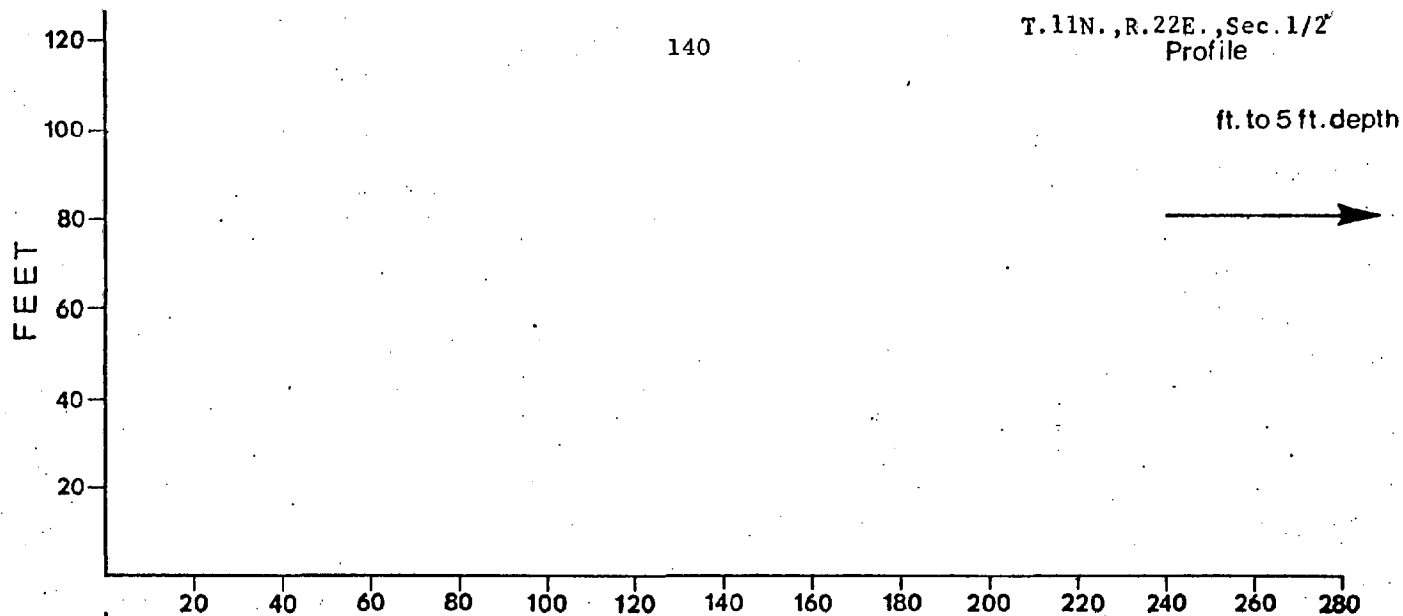
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-relatively stable, no recent failures	b- bluff 65 ft. high, constant 30° slope angle, 100% vegetation- small to large trees	c-very stable, no failures, bluff protected by sand terrace	d-bluff very low, 40 to 50 ft. gradual slope 100% vegetation- small and large trees
2. TOE	a-red-brown till slide debris	b-medium grained buff sand		
3. BEACH	a-less than 20 ft. cobbles and pebbles	b-5 to 20 ft. cobbles and pebbles	c-5 to 20 ft. very angular cobbles of bedrock	d-5 to 20 ft. clean bedrock shelf
	e-less than 20 ft. sand and pebbles	f-less than 20 ft. pebbles and cobbles (in front of certain structures the width is less than 20 ft.		



Reach 16

Reach 16 is a 3 mile stretch of Nipissing age lake terrace. The reach is located about half way between Port Washington and the Ozaukee-Sheboygan County line. Included in the reach is the northern half of section 1, T.11N., all of section 36 and 25/30 T.12N., and the southern half of section 19, T.12N.

The terrace use in this reach is entirely parkland and residential. About half of the homes are used in the summer only and half have year-round occupancy. Best access to the beaches is through any vacant lots along the lake, however cars should be left on the east-west running section line road. Sandy Beach road lends itself to easy entry because of its central location and parking area.

Reach 16 is ranked number 12 on the priority list. This is due to the number of people living on the terrace and the fragile nature of the terrace. The general conditions existing in Reach 16 are as follows.

The southern boundary of reach 16 is a small but prominent point in the middle of section 1, T.11N. The point is supported, or formed from an exposure of resistant dolomite bedrock. At the point itself there is no beach, instead a 20 feet wide shelf of bedrock dissipates the wave energy. On the northern side of the point the beach material is angular cobbles of the bedrock. This gives way to a sand beach in the pocket at 1.6.

North of the sand beach pocket the beach material becomes more coarse. The rest of the section has a cobble pebble beach which varies in width depending on the protective structures present. In almost every location the beach is wider than 20 feet.

The terrace in this stretch is a constant 275 to 300 feet wide, (except at the point itself where it is almost 500 feet wide). Behind the terrace the bluff is about 50 feet high, entirely vegetated and very stable.

The stratigraphy is difficult to obtain because of sand flowing over the toe. However near the end of the section a cut allowed the following layers to be discerned. At the base of the exposed terrace is a 1 foot layer of pebbles, overlain by 2 feet of cobbles. On top of the cobble layer was an old soil and organics layer. Over the soil is a 1 foot thick layer of loess and on top of the loess is another soil and organics layer. Over this sequence is a 3 foot layer of medium grained buff sand and the present grass surface.

In section 36, T.12N. the beach conditions are highly variable. The width changes quickly according to the structures (especially in the northern half) and to composition changes with the width. Where the beaches are wide the texture tends to be smaller grained material - sand and pebbles. Where the beach is narrow the material is coarse, either cobbles and pebbles or just cobbles. In section 36, a bedrock shelf is present from 36.5 to 36.6.

The terrace in this section is about 300 feet wide in the southern half and about 400 feet wide in the northern half. Where the bedrock forms the point the terrace is over 500 feet wide. No stratigraphy was exposed in this section. The sand completely covers the edge of the terrace giving the appearance of the terrace being completely one uniform sand layer.

The conditions present in the combined section 25/30 are very similar to those in section 36. The beach as is visible on the beach conditions map, varies in composition (texture) and width according to the structures present.

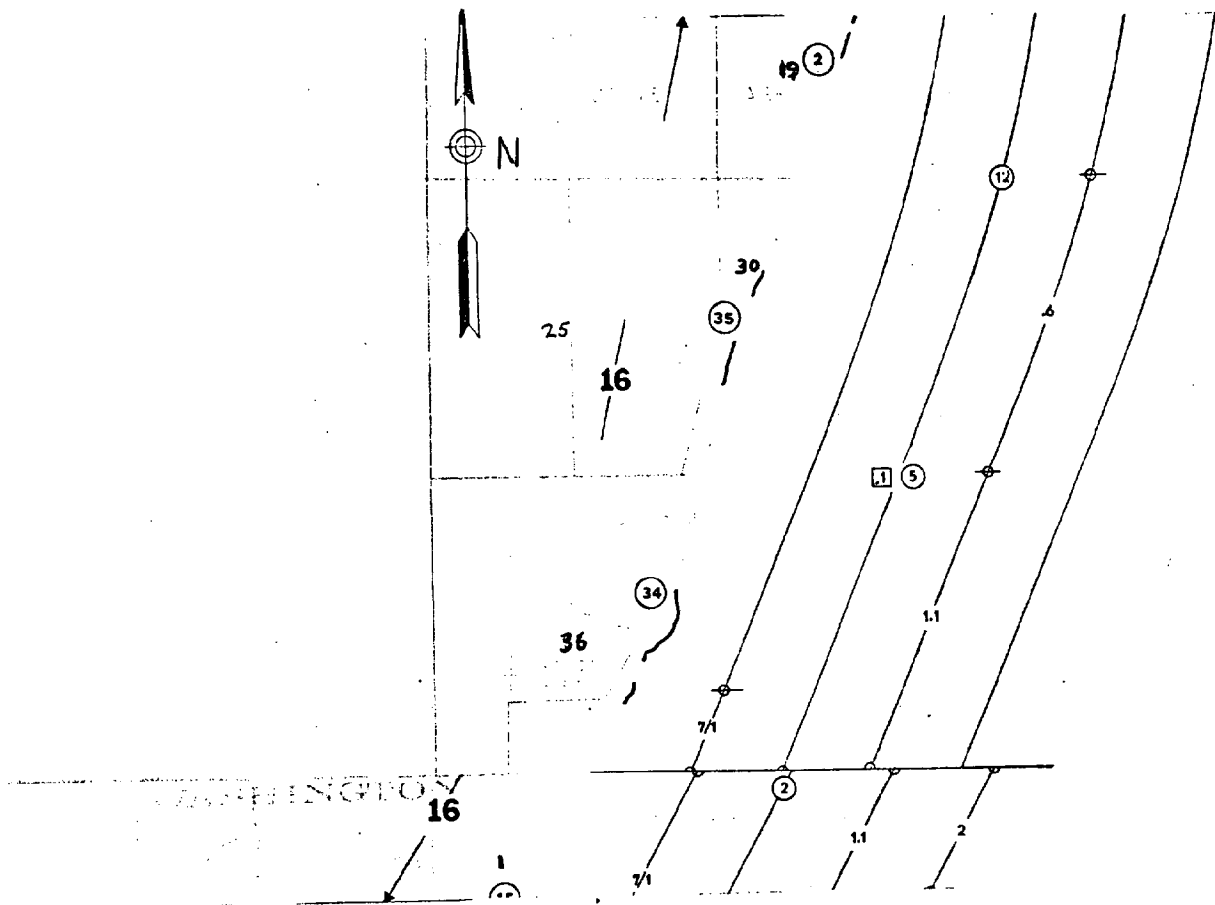
The bluff, in this stretch, completely disappears, only a gradual rise to the west is noticed. The sand terrace (although it's hard to put limits on its westward extent) seems to widen from the south (400 feet) to the north, (550 feet). No stratigraphy was recorded in this mile.

The final stretch of shore in reach 16 is the southern half of section 19, T.12N. Land use in this section is Harrington Beach Park. The beaches in the southern half of the section generally are 5 to 20 feet wide, the exception being the north-south trending stretch of shore from 19.3 to 19.4 where the beach is greater than 20 feet wide. The composition is cobbles and pebbles for the entire stretch. The northern boundary for reach 16 is the pronounced point formed from dolomite bedrock in the middle of the section. In the section is a large lake (8 feet above Michigan level) which fills an old quarry.

In this stretch as in 25/30 there is no true bluff. The stratigraphy exposed in the wave cut area of the terrace from 19.4 to 19.5 shows 11 contorted layers. These are layers of pebbly, brown-gray, and yellow silt, and cobbly-pebbly, red silts. These materials represent a regolith type deposit of the bluff material. Over these layers is 2 feet of medium sand.

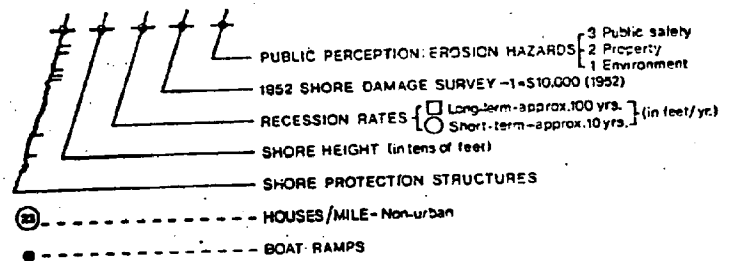
Closer to the bedrock point the stratigraphy changes and a 6 foot thick layer of small bedrock chips incorporated in a bedrock fine sand or power matrix is found directly overlying the bedrock. On top of this unit is 3 feet of clean medium grained buff sand.

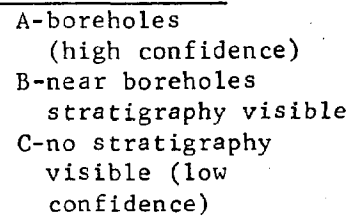
The beaches in reach 16 are in striking contrast to what they once were. Many of the owners had pictures and tales to tell of the days when the beaches were 200 feet wide and made of pure sand. The sand that formed those beaches has now been removed by the currents which run parallel to the N 20' to N 30' E trend of the shore in this area. All that is left of sand is now incorporated into 3 sand bars. One close to shore (25 feet), the second further out (150 ft.), and the third only present in certain localities is far from shore. The second bar accounts for the distant 5 foot depth measurement. With this large amount of sand present it seems that groins would be the ideal type of protective structure for this reach. The southern most groin should be placed so that any erosive forces produced by it are directed on the bedrock point in section 1, T.11N.



Reach 16

1 mile



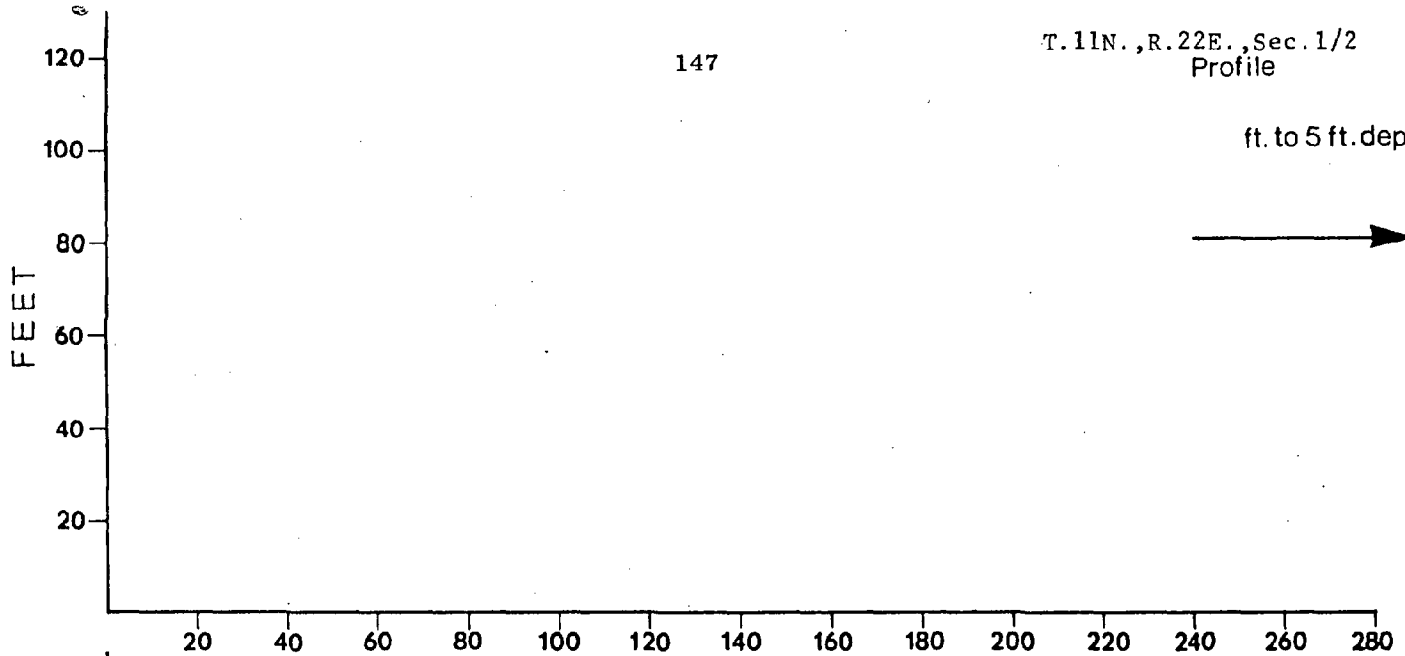


1. BLUFF	a-relatively stable, no recent failures	b- bluff 65 ft. high, constant 30° slope angle, 100% vegetation- small to large trees	c-very stable, no failures, bluff protected by sand terrace	d-bluff very low, 40 to 50 ft. gradual slope 100% vegetation- small and large trees
2. TOE	a-red-brown till slide debris	b-medium grained buff sand		
3. BEACH	a-less than 20 ft. cobbles and pebbles	b-5 to 20 ft. cobbles and pebbles	c-5 to 20 ft. very angular cobbles of bedrock	d-5 to 20 ft. clean bedrock shelf
	e-less than 20 ft. sand and pebbles	f-less than 20 ft. pebbles and cobbles (in front of certain structures the width is less than 20 ft.		

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T.11N., R.22E., Sec. 1/2
Profile

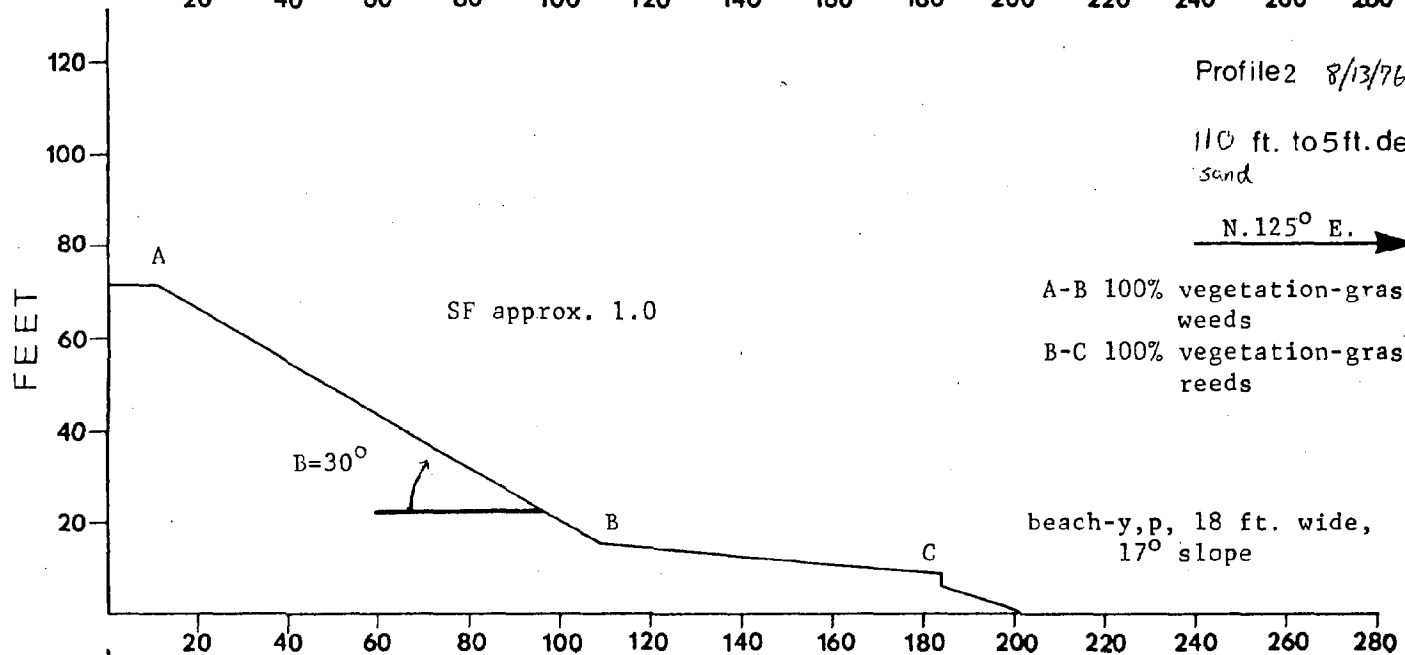
ft. to 5 ft. depth



Profile 2 8/13/76

110 ft. to 5 ft. depth
sand

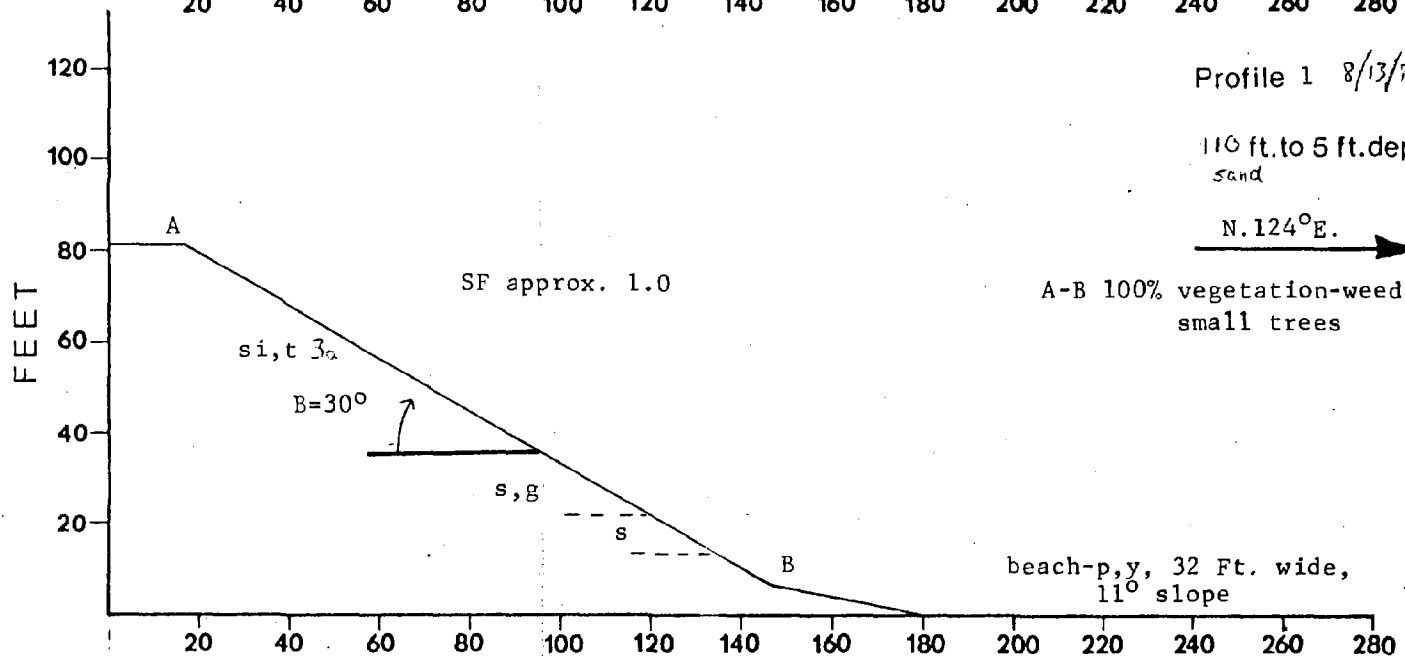
N. 125° E. →

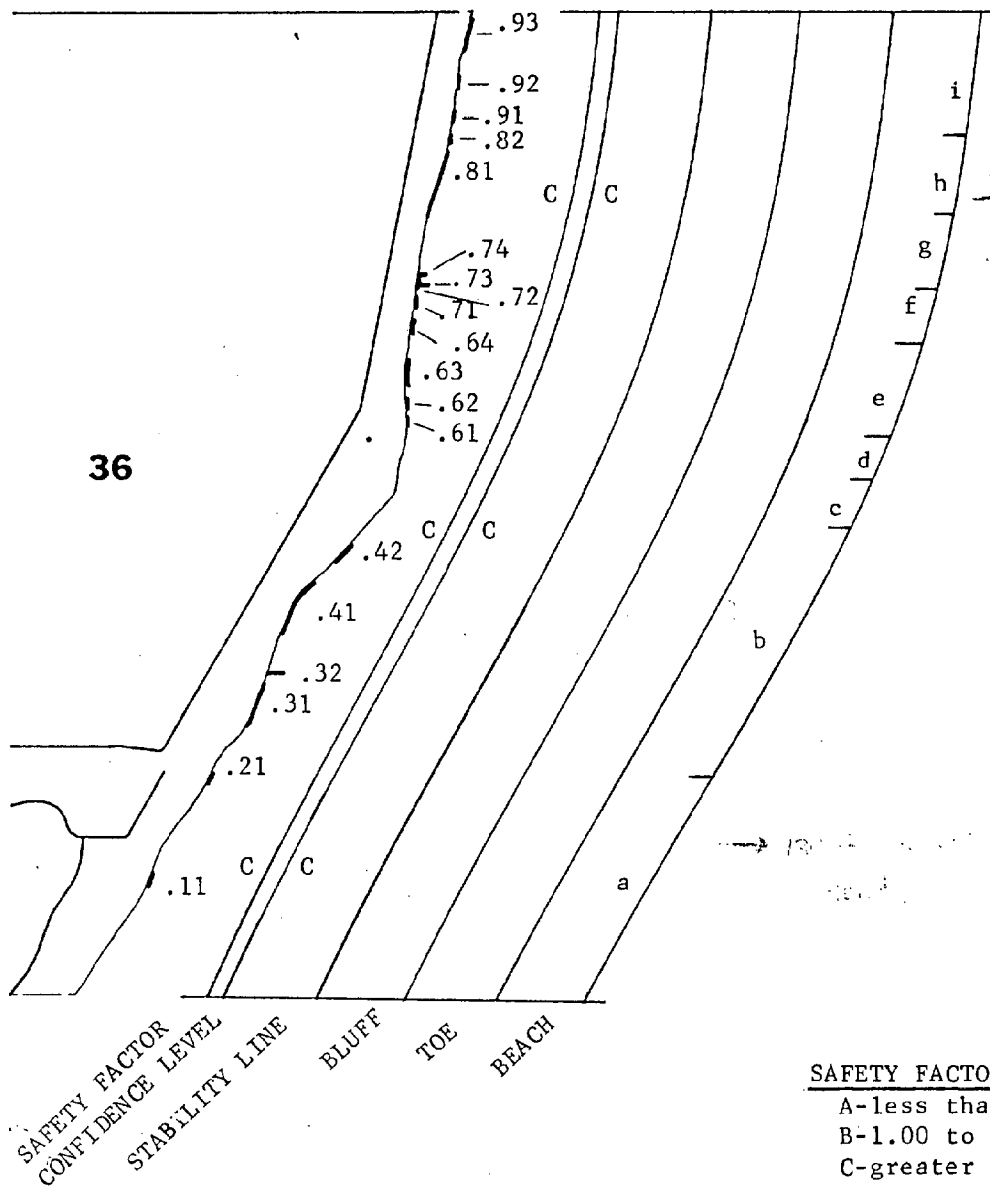


Profile 1 8/13/76

110 ft. to 5 ft. depth
sand

N. 124° E. →



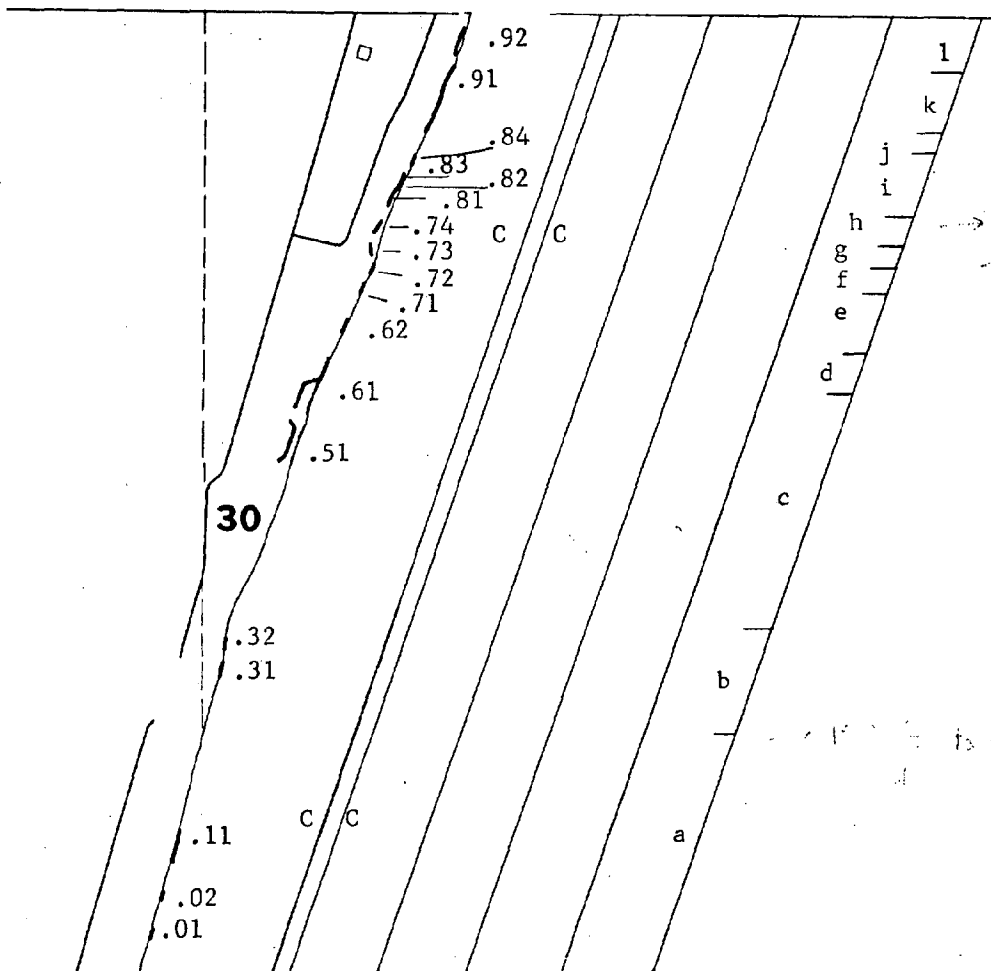
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-no boreholes
stratigraphy visible
- C-no stratigraphy
visible (low confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-less than 20 ft. cobble and pebbles with sand mixture	b-5 to 20 ft. cobbles and pebbles	c-20 ft. bedrock shelf	d-less than 20 ft. angular bedrock cobble
	e-5 to 20 ft. rounded cobble	f-0 to 5 to 20 ft. cobble and pebbles	g-less than 20 ft. pebbles, cobble and sand	h-5to20 ft pebbles and cobble
	i-less than 20 ft. pebbles and cobble and sand			



SAFETY FACTOR
CONFIDENCE LEVEL
STABILITY LINE

BLUFF

TOE

BEACH

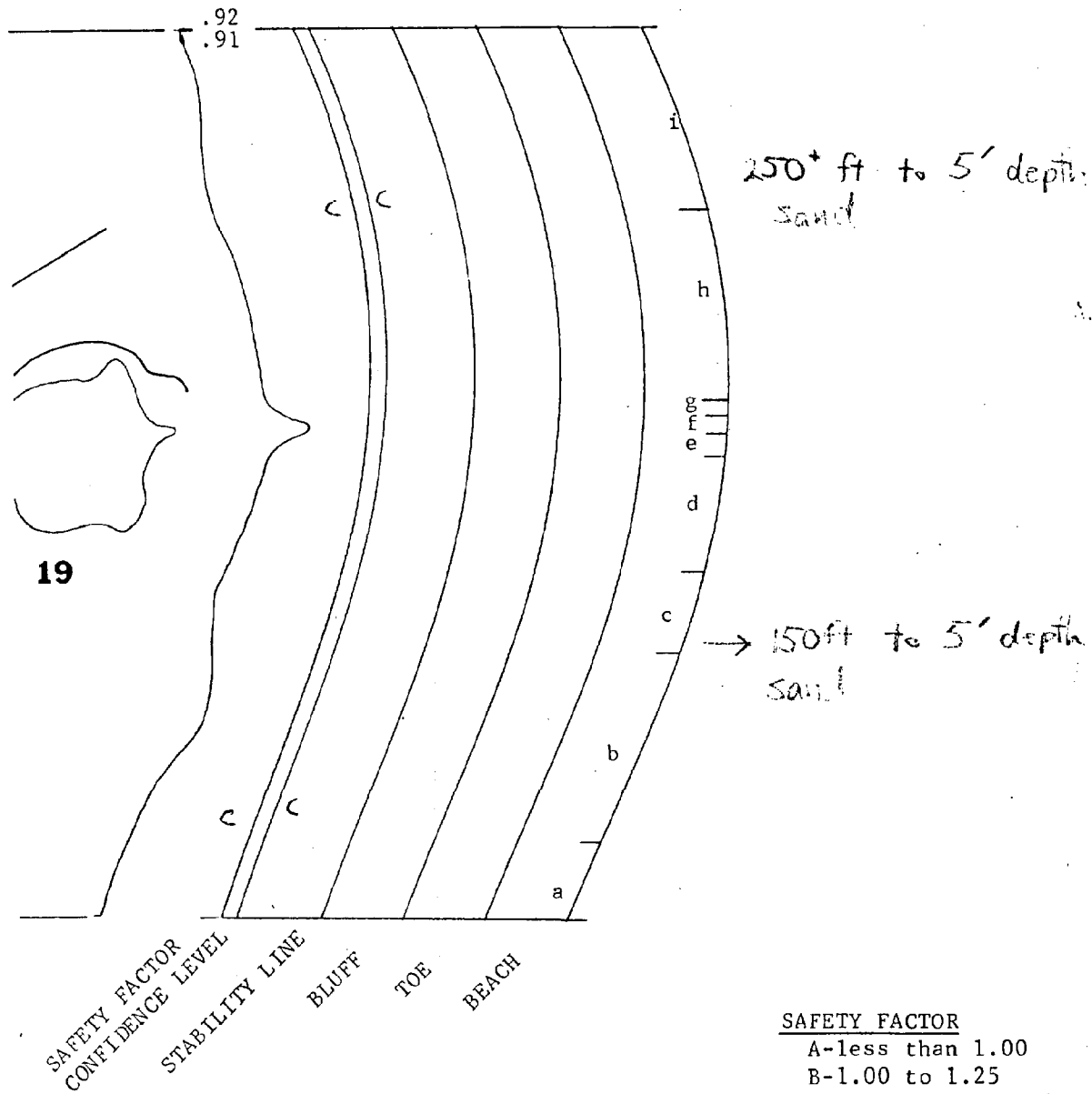
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-less than 20 ft.sand, pebbles and cobbles	b-5 to 20ft. sand and cobbles	c-less than 20ft. sand and pebbles	d-5 to 20ft. pebbles
	e-less than 20 ft.	f-5 to 20ft.	g-no beach	h-5 to 20 ft.
	i-no beach	j-5 to 20 ft. pebbles and cobbles	k-5 to 10 ft. pebbles and cobbles	l-0 to 10 ft. cobbles

SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-15 to 25ft. cobbles and pebbles	b-5 to 20 ft. cobbles and pebbles	c-less than 20 ft. cobbles and pebbles	d-5 to 20 ft. pebbles and cobbles
	e-5 to 20 ft. sand	f-5 to 20 ft. bedrock shelf with angular cobbles	g-5 to 20 ft. angular bedrock cobbles	h-less than 20 ft. sand (over 50 ft. in place)
	i-less than 20 ft. bedrock shelf with angular cobbles and sand			

Reach 17

Reach 17 is a $3\frac{1}{2}$ mile stretch of Nipissing age lake terrace. It is located at the northern end of Ozaukee County and extends from the point at Harrington Beach north to the Ozaukee-Sheboygan County Line. Included in the reach is the northern half of section 19 T.12N. and all of section 18, 7, and 6, T.12N.

The land in reach 17 is used primarily for residential purposes but includes the park in section 19. Best access to this reach is through either Lake Church or Jay Roads which both dead end at the water.

Reach 17 is ranked number 13 on the erosion study priority list. This is due to the concentration of people living in the area and the easily eroded terrace material.

The reach has its southern boundary at the bedrock point in Harrington Beach Park, section 19, T.12N. At the point there is no beach, only a 20 foot wide bedrock shelf. On the northern side of the point the beach is 5 to 20 feet wide and composed of angular cobbles of the dolomite bedrock. In the pocket (formed by the point and normal shore) and extending north to 19.8 is a very wide (up to 100 feet) sand beach. Associated with the beach is a maze of sand bars which extend from the point beyond the northern end of the section. These sand deposits are caused by the groin like action of the point, and the bedrock which is close to lake level 300 feet from shore. The bedrock is exposed at water level from 19.85 to 19.99.

The stratigraphy in this area of the terrace has small dolomite (bedrock) chips incorporated in a matrix bedrock fine sand and powder, (6 feet thick) overlain by 3 feet of medium grained buff sand. Beyond the terrace there is no true bluff only a gradual slope.

Section 18 has residential areas in the southern $\frac{1}{4}$ and the northern $\frac{1}{4}$ of the stretch. The central $\frac{1}{2}$ mile is not developed. The beach conditions reflect this situation. The beaches (though they are still greater than 20 feet wide in places) are more narrow at both ends of the section than they are in the central part of the section. The texture of the beaches throughout the section is a medium grained sand.

It is hard to determine the width of the terrace in this area because there is no bluff marking the western terrace edge. (There is only a long gentle rise.)

The position of sand bars and the edge of the bedrock shelf are easily visible in the overhead air photos.

The beach conditions in section 7 are in part determined by the presence or absence of protective structures. Where there are structures the beach width is limited; where there are not structures the beach tends to be wider. The chopped up appearance of the beach width map reflects these conditions. Throughout the section the beach material is sand.

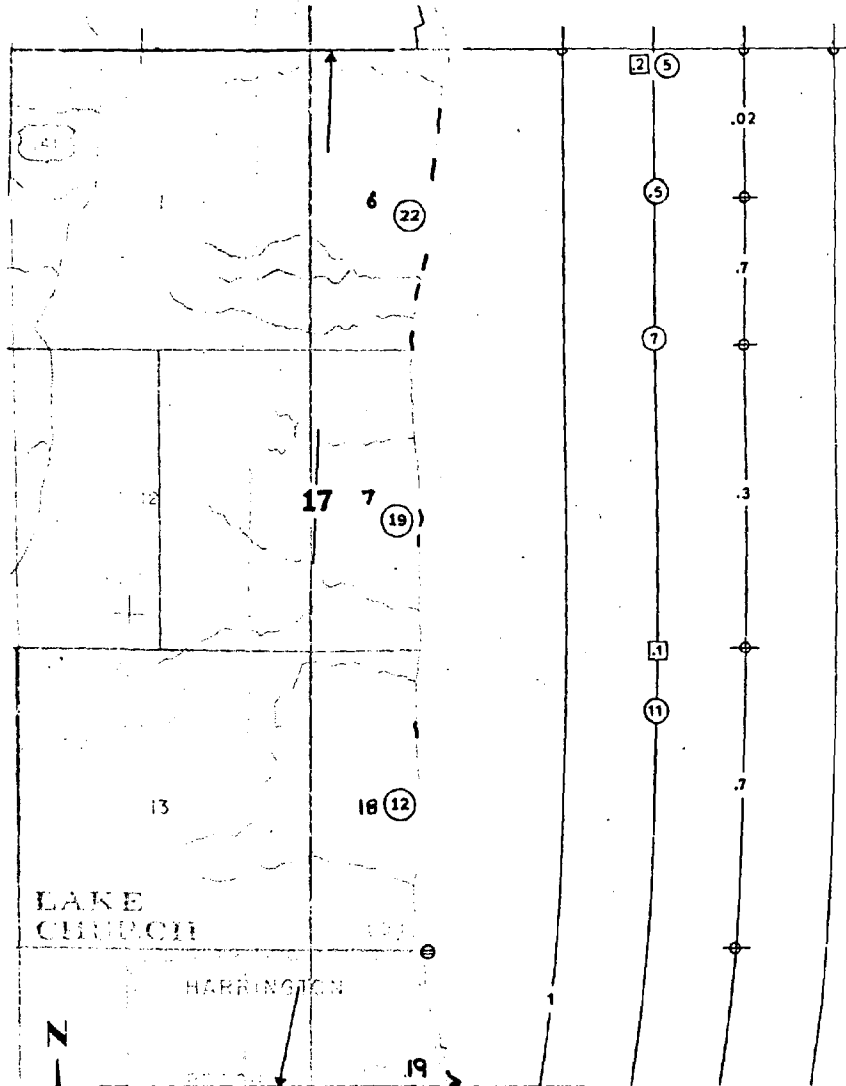
In the southern parts of section 7 there is no bluff, however at 7.24 a slight but noticeable step appears and rises to the north forming a small bluff. At the northern section line the terrace is about 700 feet wide.

No stratigraphy was obtained in section 7.

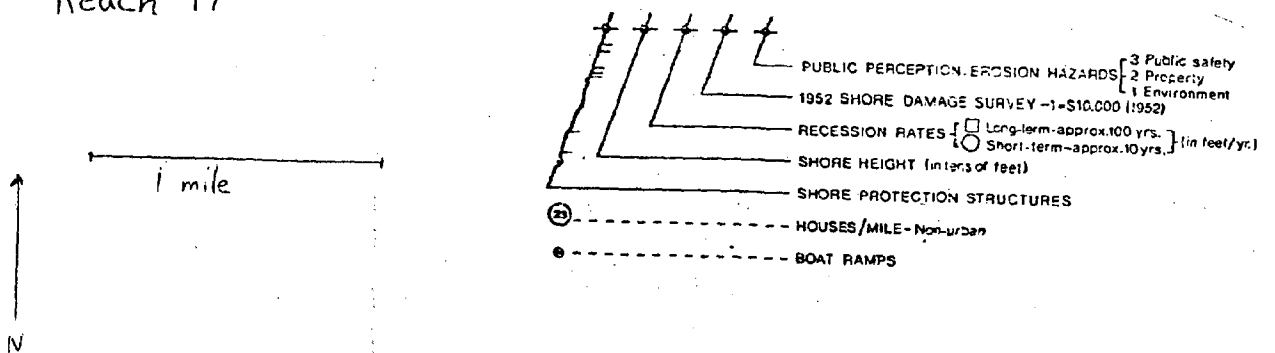
In section 6 the conditions present in the other populated areas of the terrace are continued. The beach width is determined by the structures present and the texture is sand with a few pebbly areas.

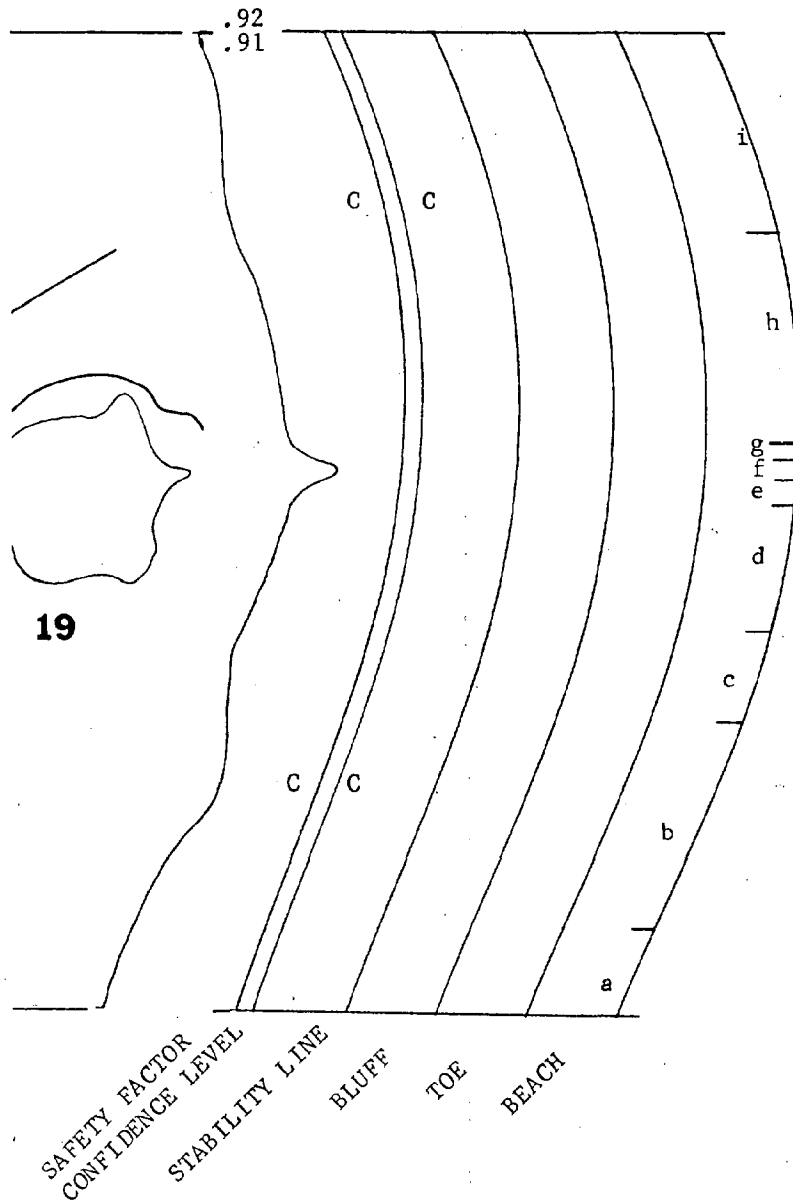
The low bluff which started in section 7 continues through section 6. Although it was not measured it appears to be about 30 to 40 feet high. The terrace in this section ranges from 700 feet at the southern end to 600 feet in the middle of the section, and widens to over 1000 feet at the northern end of the section. No stratigraphy was obtained in section 6.

Throughout most of Reach 17 three sand bars are present. One close to shore (25 feet), a second about 150 feet out and a third almost 500 feet offshore. With this large quantity of sand at hand it seems that groins should be the ideal type of protective structure for this reach. The most southern groin could be situated so that any erosion it produces would be directed on the bedrock point in section 19.



Reach 17



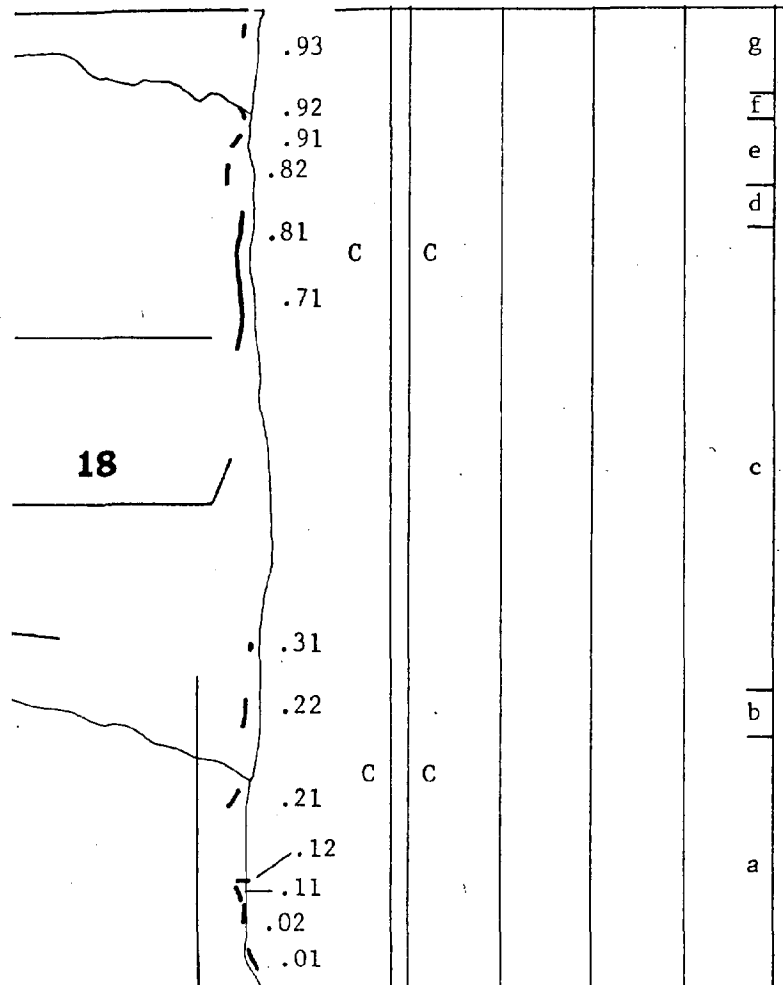
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25.
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-15 to 25ft. cobbles and pebbles	b-5 to 20 ft. cobbles and pebbles	c-less than 20 ft. cobbles and pebbles	d-5 to 20 ft. pebbles and cobbles
	e-5 to 20 ft. sand	f-5 to 20 ft. bedrock shelf with angular cobbles	g-5 to 20 ft. angular bedrock cobbles	h-less than 20 ft. sand (over 50 ft. in place)
	i-less than 20 ft. bedrock shelf with angular cobbles and sand			



SAFETY FACTOR
CONFIDENCE LEVEL
STABILITY LINE
BLUFF
TOE
BEACH

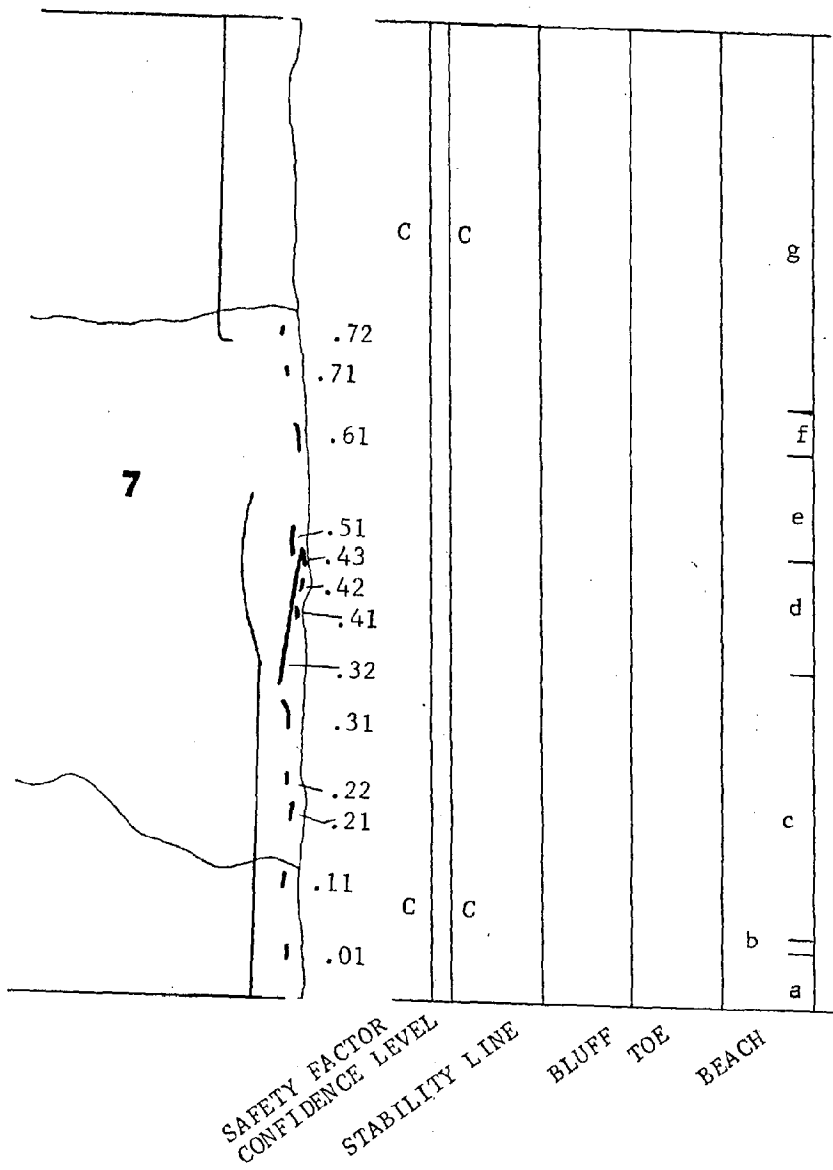
SAFETY FACTOR

A-less than 1.00
B-1.00 to 1.25
C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes
(high confidence)
B-near boreholes
stratigraphy visible
C-no stratigraphy
visible (low
confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-less than 20 ft. sand	b-5 to 20ft. sand	c-less than 20 ft. sand	d-5 to 20 ft. sand
	e-less than 20 ft. sand	f-5 to 20 ft. sand	g-less than 20 ft. sand	

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

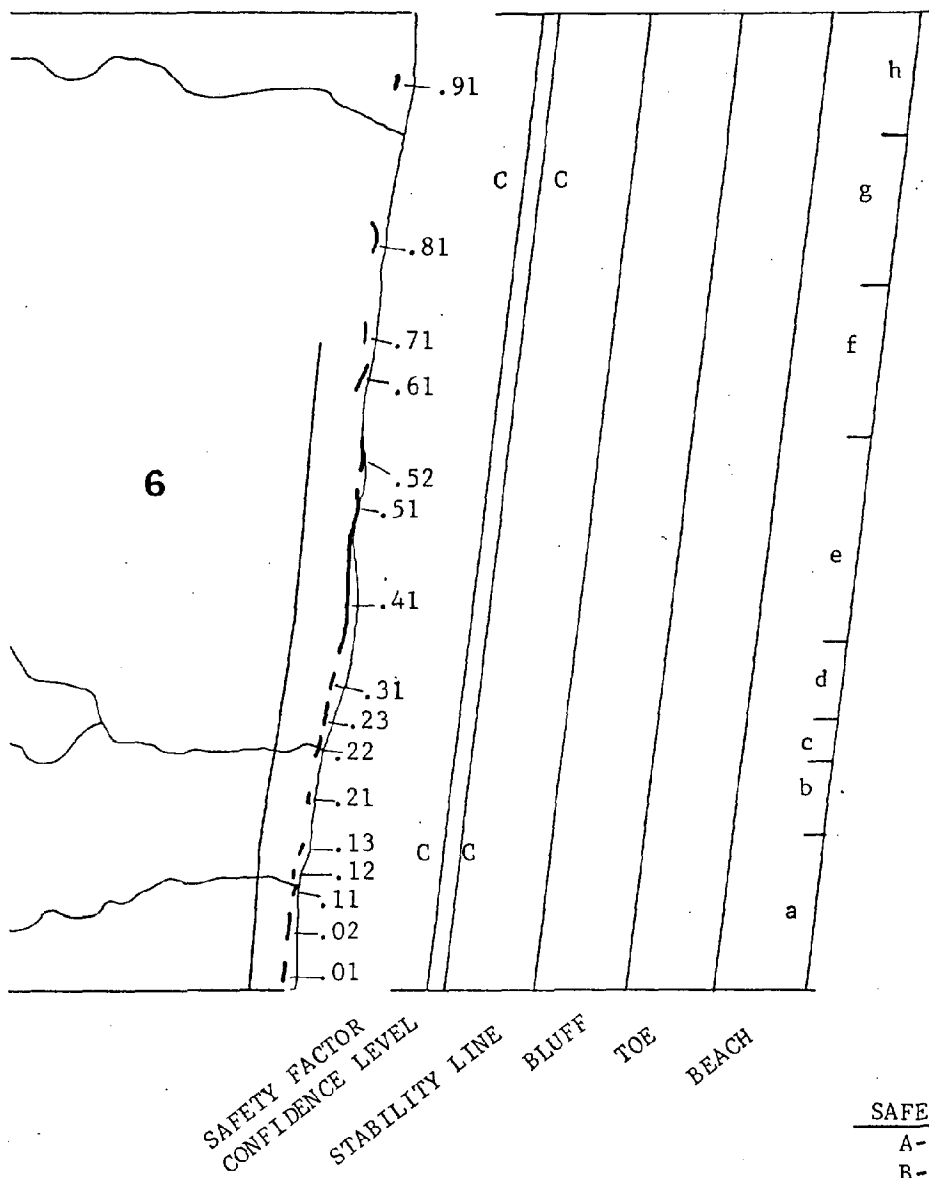
B-near boreholes

stratigraphy visible

C-no stratigraphy

visible (low
confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-less than 20 ft. sand	b-5 to 20 ft. sand	c-less than 20 ft. sand	d-5 to 20 ft. sand
	e-less than 20 ft. sand	f-no beach	g-less than 20 ft. sand	

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVELA-boreholes
(high confidence)B-near boreholes
stratigraphy visibleC-no stratigraphy
visible (low
Confidence)

1. BLUFF				
2. TOE				
3. BEACH	a-5 to 20 ft. sand and pebbles	b-less than 20 ft. sand	c-5 to 20 ft. sand and pebbles	d-less than 20 ft. sand
	e-5 to 20 ft. sand and pebbles	f-less than 20 ft. sand	g-5 to 20 ft. sand	h-less than 20 ft. sand

COASTAL ZONE
INFORMATION CENTER

